SELF-DEPLOYING SPACE STATION

FINAL REPORT

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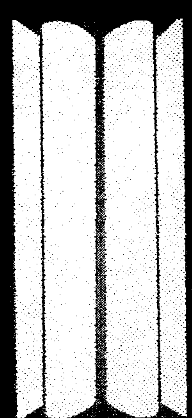

NORTH AMERICAN AVIATION, INC. SPACE and INFORMATION SYSTEMS DIVISION

(NASA Contract NAS1-1630)

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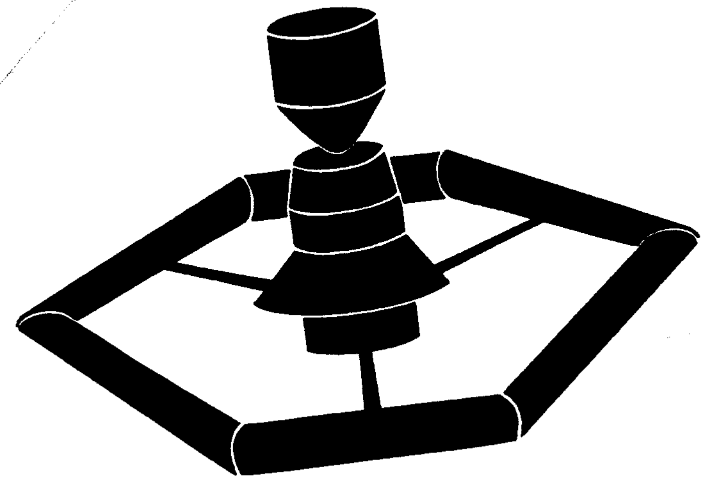

SELF-DEPLOYING SPACE STATION

2 *FINAL REPORT*

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Downey, Calif.

FOREWORD

This document is the final report to be prepared by the Space and Information Systems Division of North American Aviation, Inc. under NASA Langley Research Center Contract NAS1-1630, "Self-Deploying Space Station", dated 27 October 1962.

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INTRODUCTION

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The six-month feasiblity study of a Self-Deploying Space Station (SDSS) concept devised by the Langley Research Center was initiated on 27 October 1961. After a series of configuration evolutions and system refinements by S&ID, a vehicle was designed which was believed to represent a feasible SDSS concept. To further substantiate the feasibility of the design, the contract effort was formally extended on 27 April 1962 to include the design and construction of a 1/10-scale model of the selected SDSS vehicle configuration. It was intended that the model be fully automatic (i. e. self-deploying) and that the deployment mechanism be similar to that which would be used on a full-sized space station.

The Mid-Term Report, SID 62-191, and the Interim Report, SID 62-658 (three volumes), both previously submitted, present the analyses relating to the "operational" SDSS, which was conceptually established. The primary objective of this final report is to describe those additional activities relating to the design, construction, and operation of the 1/10-scale deployment model. It also contains a section describing problem areas which should be given particular consideration in the subsequent development of the SDSS. The model constructed under this contract was shipped to the NASA Langley Research Center, reassembled and checked out on 12 October 1962. Delivery was expedited at special request of NASA; since this was about two weeks earlier than the established delivery date, S&ID was unable to complete measurements and functionally evaluate the model to the degree desired. Consequently, a series of recommended measurements and experiments are included in this report. AUTHOR

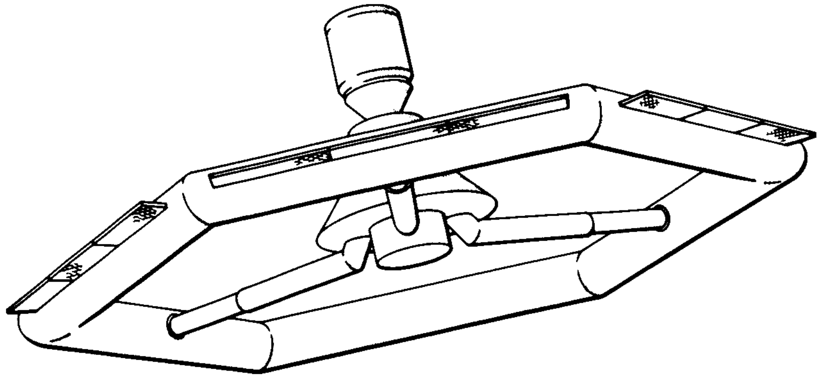
SUMMARY

The Self-Deploying Space Station (SDSS), evolved through a six-month feasibility study, is a 150-foot-diameter, all-rigid vehicle, which can be folded into a compact configuration for launch into orbit by a single Saturn C-5 (S-IC plus S-II). The space station, illustrated in Figure 1, is composed of six cylindrical modules arranged in a hexagonal configuration. Three telescoping spokes connect the modules to a central hub, which is used as a docking facility for Apollo-type personnel transport vehicles. It also houses a 3200-cubic-foot, zero-gravity compartment. Each module has an overall length of 75 feet and is self-sufficient in possessing independent environmental control, life support, and power systems. Airlocks at each major space station element connection (i. e., module-to-module, module-to-spoke, and spoke-to-hub) further prevent malfunction or accident in an individual element from jeopardizing the entire SDSS operation. The complete design of the SDSS was based on the use of currently avaiiable technology.

A unique hinging arrangement enables the space station to be deployed from a folded launch configuration to the hexagonal configuration. Several small (1/50-scale) manually operated models were made to demonstrate the concept. However it was realized that a larger, more precise, automatically deploying model would be required to substantiate its practicability. A 1/10-scale model – small enough to be built at a nominal cost, yet large enough to avoid the necessity for miniaturized components – was subsequently designed and constructed by S&ID under an extension to the basic feasibility study contract.

In designing the model, no attempt was made to duplicate those aspects of the SDSS not pertinent to demonstration of SDSS kinematics. Therefore, the framework of the model does not resemble the multiwall structure previously recommended for the SDSS, and it embodies none of the functioning systems of the space station other than the deployment mechanisms. Component dimensions, hinge positions, actuator locations, etc., were established with low tolerances so as to yield a precise unit that can be used to provide realistic design parameters. However, no analysis has been conducted to establish the necessity for tolerance restrictions.

The model is composed of six aluminum modules (1 foot in diameter) hinged to form the desired hexagonal configuration. Three aluminum,



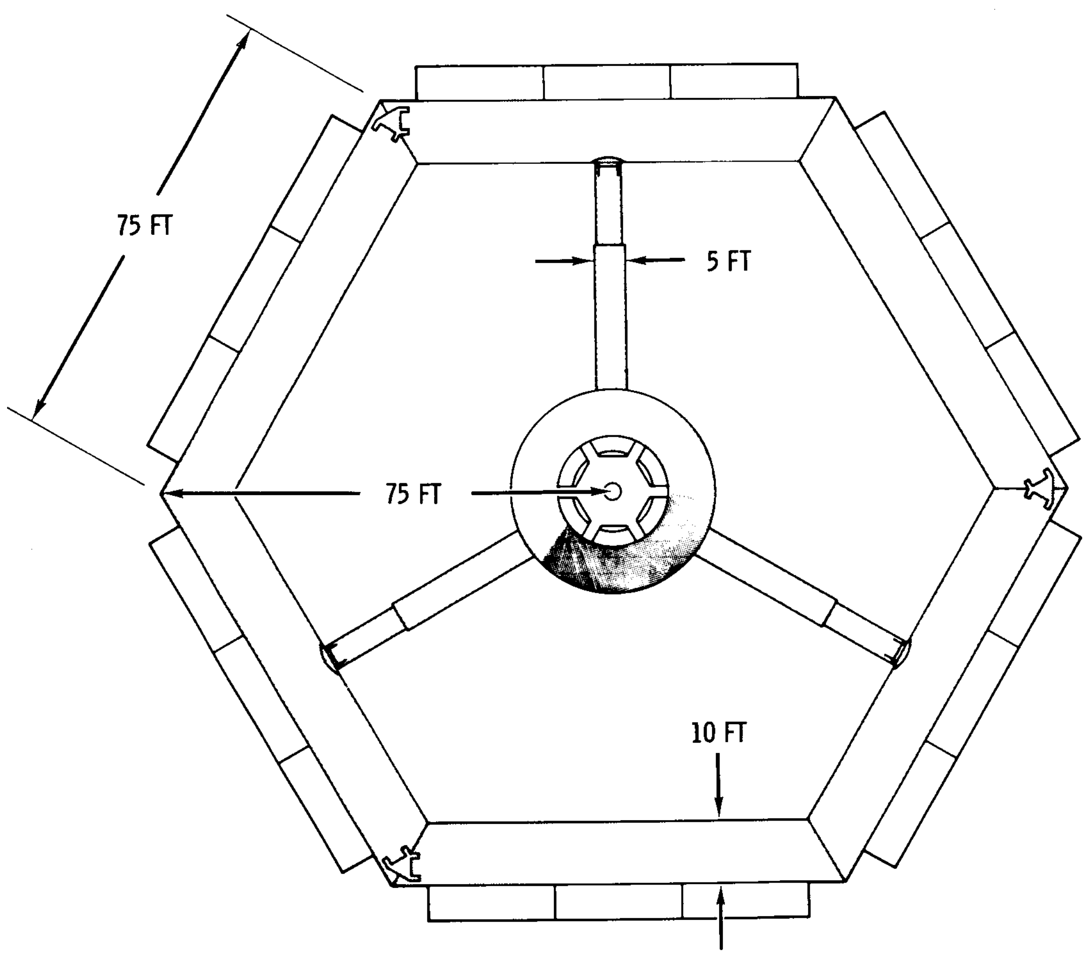


Figure 1. Current SDSS Design

two-section telescoping spokes connect alternate modules with the hub as in the conceptional SDSS design. The hub is composed of a heavy steel plate upon which is mounted the spoke actuation mechanism; a light-weight fiberglass fairing forms the hub contour. Another fiberglass fairing is used to represent the interstage between the SDSS and the S-II booster stage. The 700-pound model is supported from a tripod structure by an electric hoist, which enables it to be raised or lowered for convenient maintenance. The 1/10-scale model of the SDSS was constructed in accordance with detail design drawings and specifications produced by the Space and Information Systems Division. A series of photographs, showing the model in various stages of deployment, is presented in Figures 2 through 10.

Since analysis indicated that precise symmetry was required for successful model deployment, all motions of the model components are fully and uniformly controlled. Twelve identical, electrically driven screw-jack actuators in the modules--two at each joint--provide the necessary "coordinated" module motion. A heavy spring connected to a cable and pulley mechanism ensures that all three spokes remain at equal lengths throughout the deployment cycle. The angle between the spokes and a vertical centerline through the hub is controlled by three actuators--one for each spoke--which are identical to those used in the modules. The motors in the electrical actuators are not synchronized; however, they are designed to operate at a rate which will not vary by more than two percent among all fifteen actuators if the design load is not exceeded.

The screw-jack actuators are similar to those which control the flaps on commercial jet airliners. They were designed and constructed under subcontract to S&ID. The module actuators carry a load of approximately 80 pounds, while the spoke actuators carry about 830 pounds. Eighteen actuators were procured so three spares would be available. All actuators were designed to carry 1000 pounds of load, with no reduction in motor speed. The duration of the operating cycle was specified as 120 seconds. Due to an unexpected efficiency loss in the gear train, the actuators as originally built did not meet the load specifications. Consequently, it was necessary to place ballast in the hub to reduce the spoke actuator load to about 500 pounds. While this enables the model to operate satisfactorily, it is not believed to be an optimum arrangement. Therefore, six of the actuators are being modified at the subcontractor's expense to meet the original specifications.

The model operation is controlled from a small console by a simple toggle switch. Each actuator is stopped independently by microswitches, installed at appropriate locations near the actuators, when it has traveled

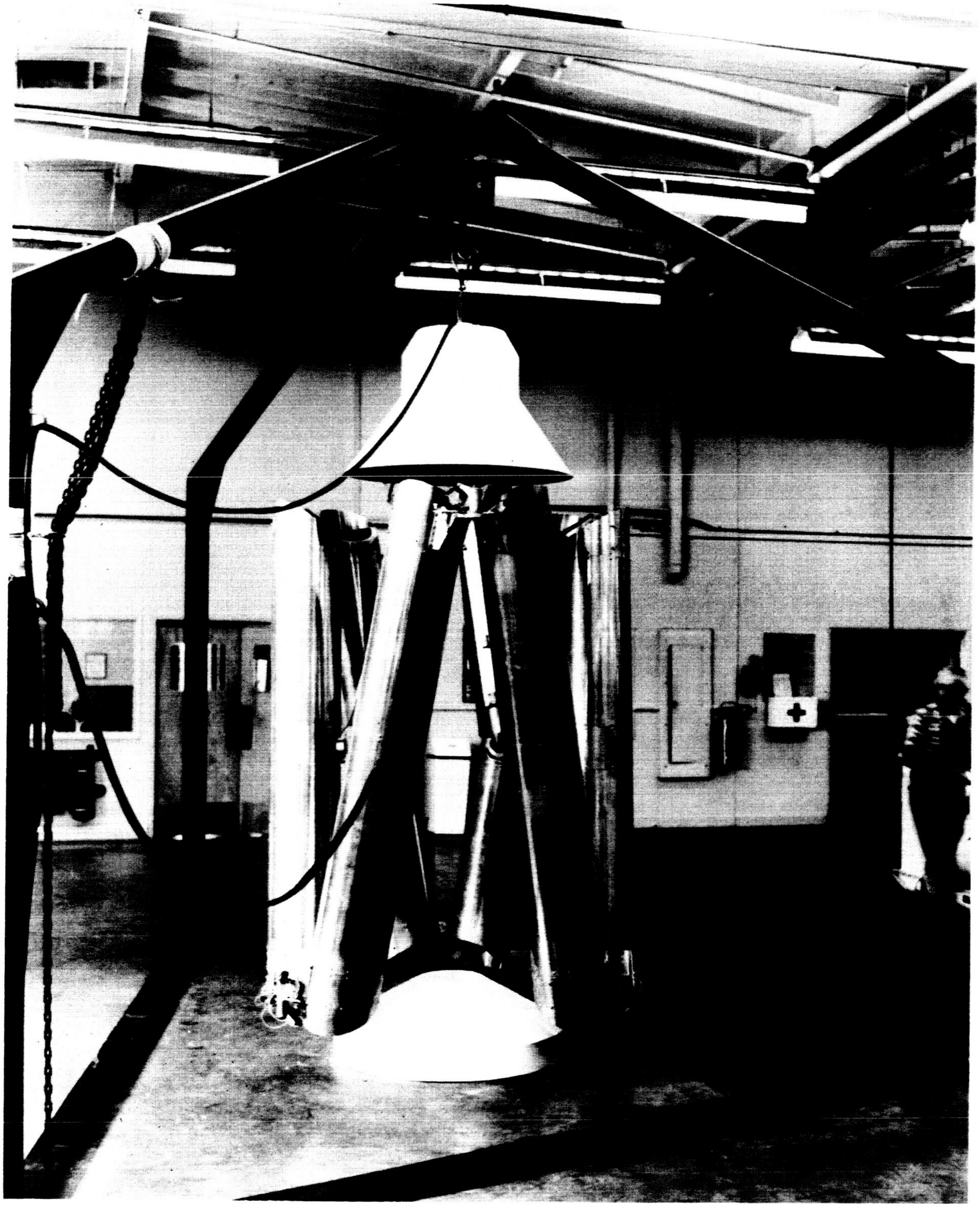


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Figure 3. Deployment Sequence -B

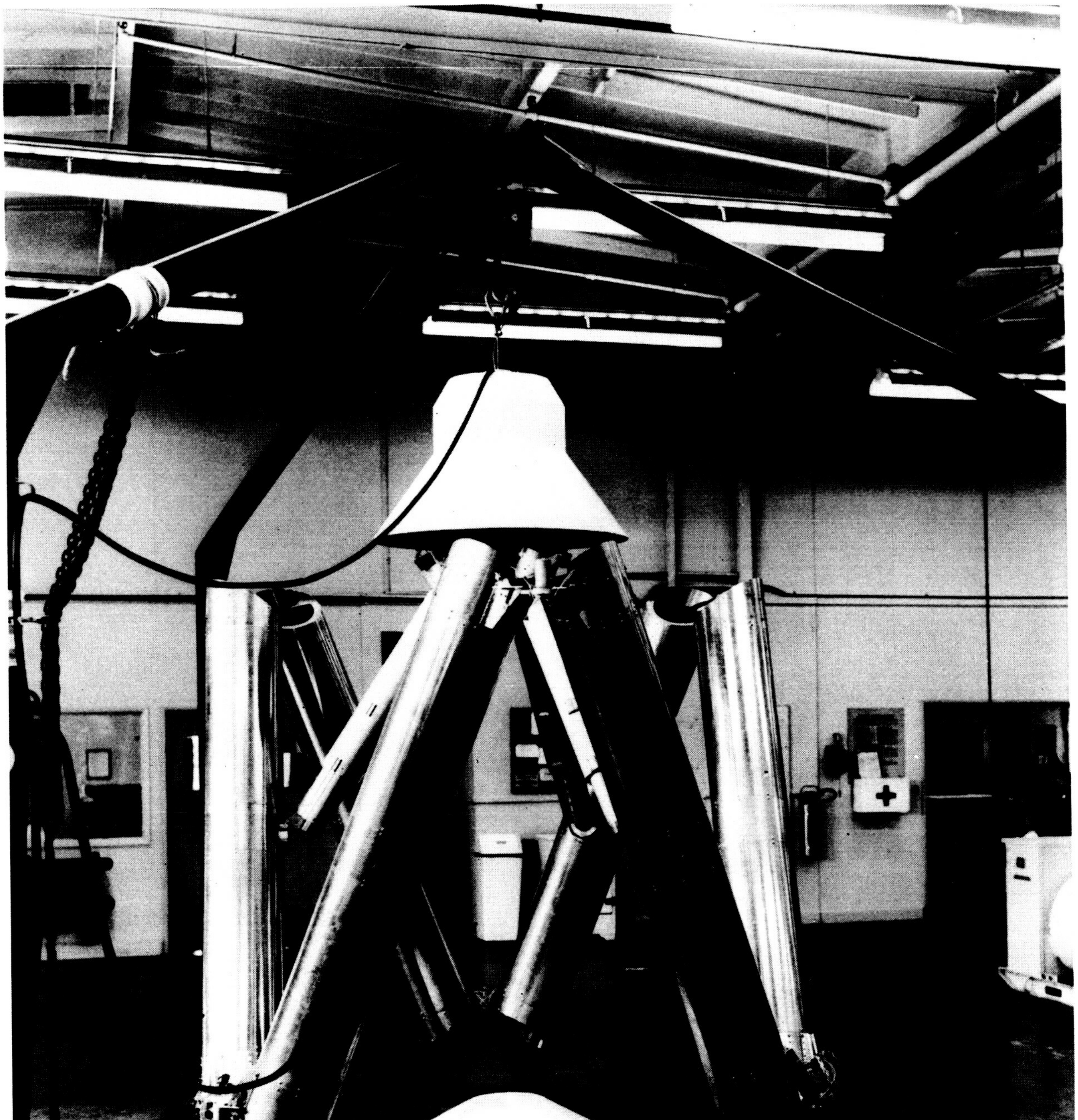

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Figure 4. Deployment Sequence -C

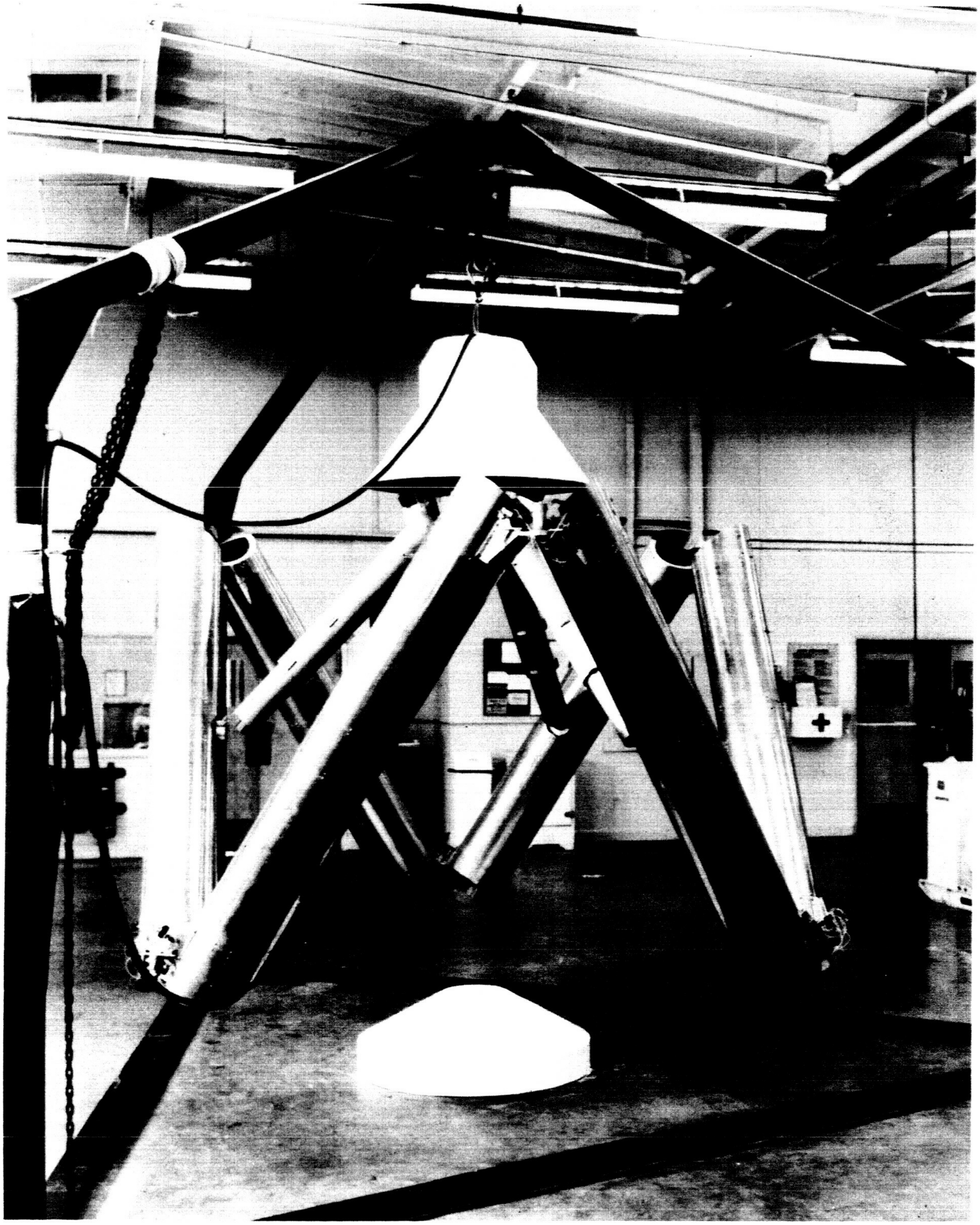

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Figure 5. Deployment Sequence -D

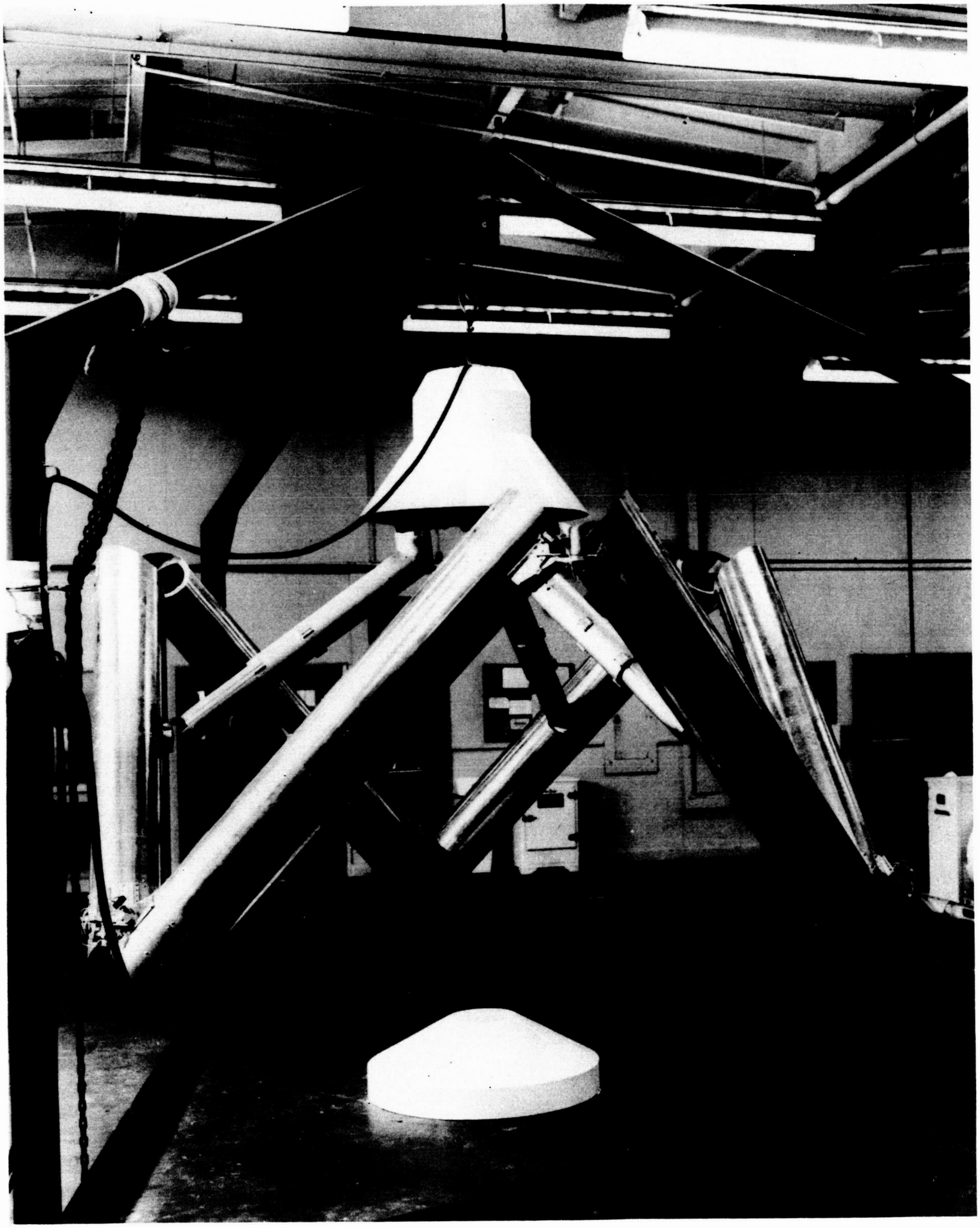

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Figure 6. Deployment Sequence -E

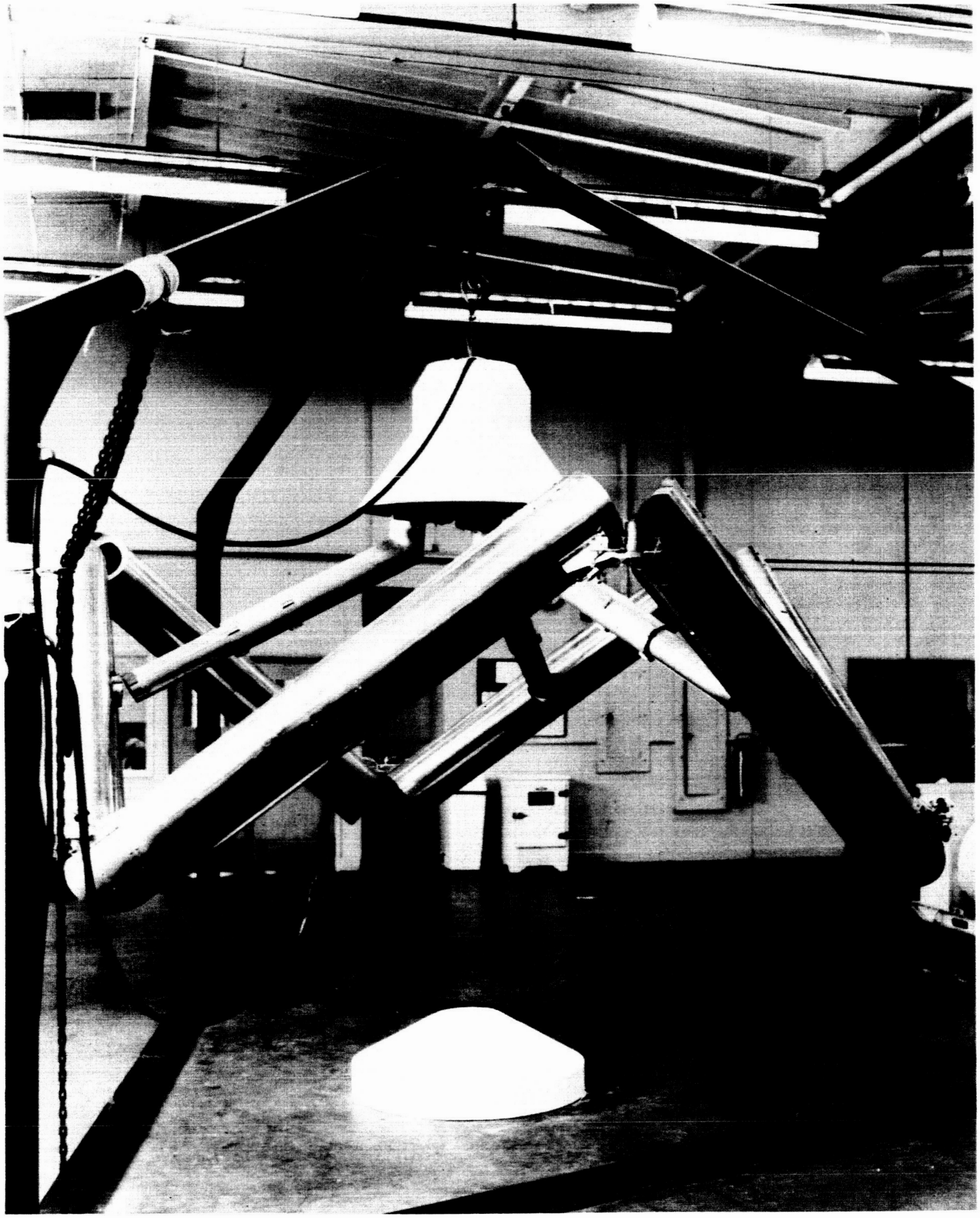

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Figure 7. Deployment Sequence -F

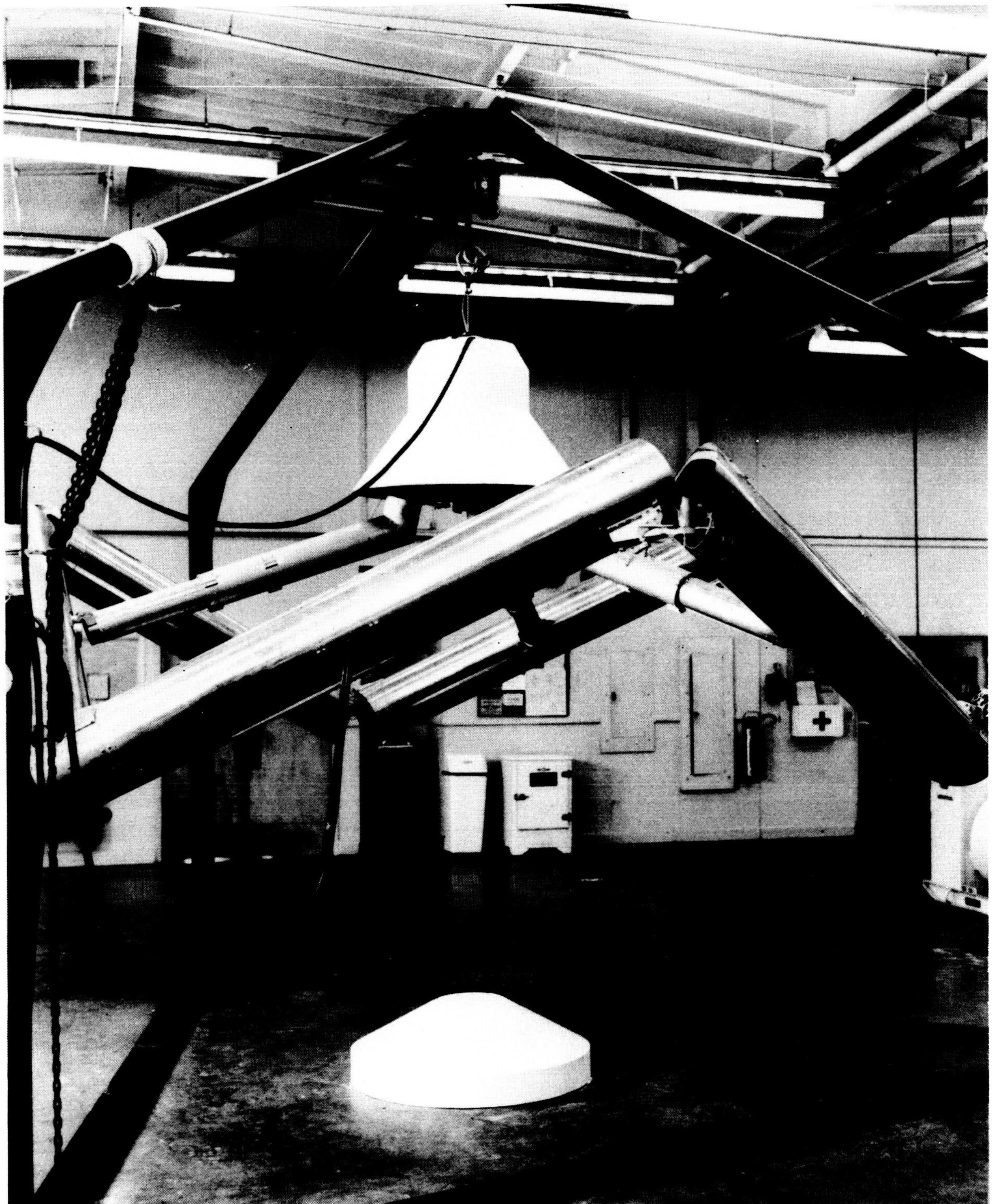

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Figure 8. Deployment Sequence -G

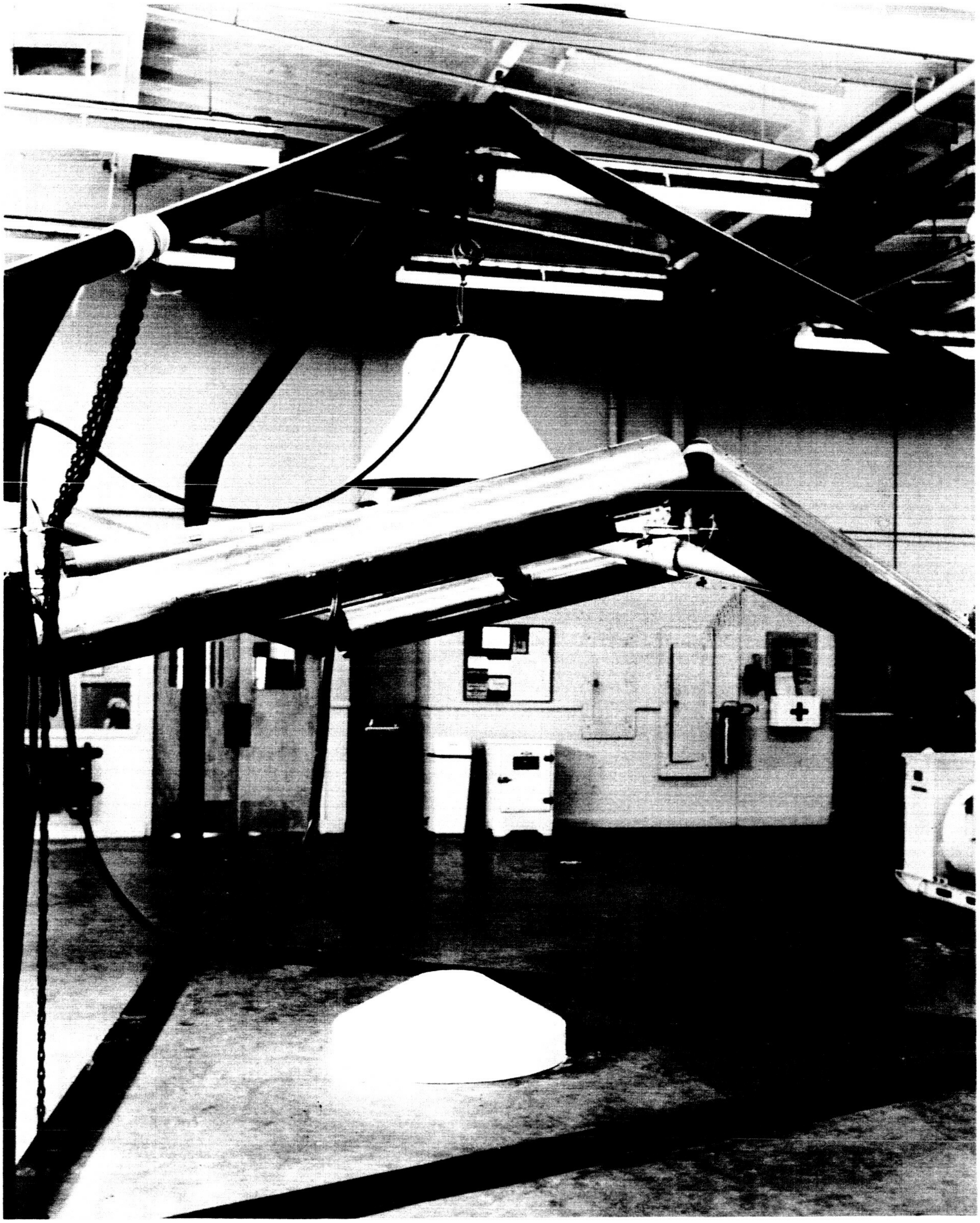

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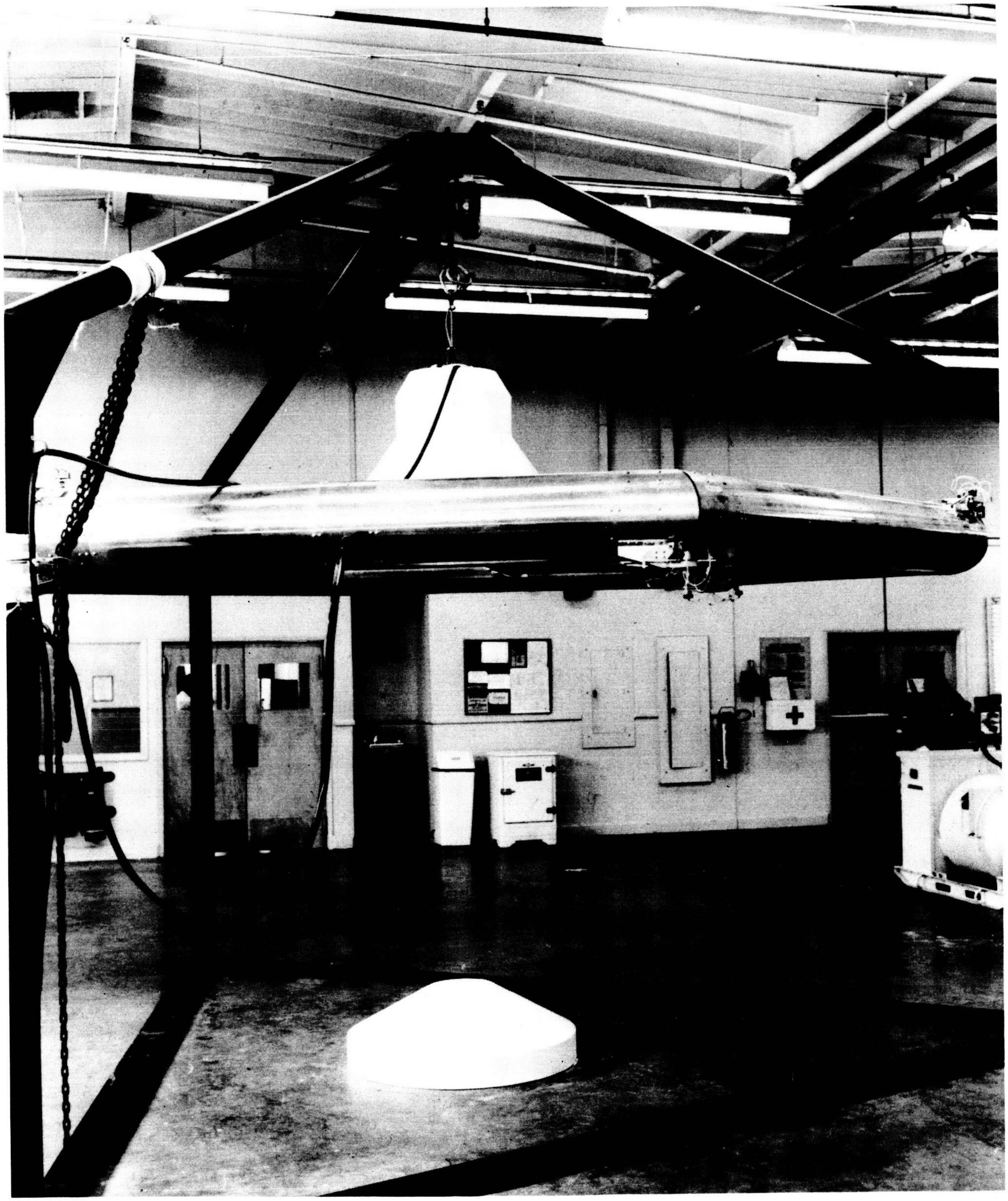
Figure 9. Deployment Sequence -H



700-98-157

Figure 10. Deployment Sequence -I

a pre-determined distance. A reverse direct current is applied to the motor armature to prevent over-run. After the deployment cycle is completed, the operator can reverse the switch, permitting the model to re-fold itself into the launch configuration in preparation for the next deployment cycle.

The first deployment of the model was successfully demonstrated on 27 September 1962. An additional sixteen deployment cycles were accomplished by S&ID before the model was shipped to the NASA Langley Research Center on 5 October 1962. S&ID believes the model has adequately demonstrated the practicability of deployment of an all-rigid self-deploying space station. The 1/10-scale model, in conjunction with the earlier six-month feasibility studies, has led to the conclusion that the SDSS is feasible and can be made operational in the 1966 time period.

To provide more detailed data for use in the design and development of the deployment mechanism of a full-scale operational SDSS, it is suggested that several experiments be performed and measurements taken, using the model at Langley Research Center. Of particular interest would be a determination of the fewest actuators required for deployment, the amount of asymmetry to be tolerated before joints bind, and the actual loads on each actuator. Other experiments of interest will be described later in this report.

1. TECHNICAL DISCUSSION

MECHANICAL DESIGN

A 1/10-scale model of the recommended SDSS configuration was designed and fabricated to demonstrate the general feasibility of the kinematic concept and to investigate deployment system problems. Close coordination with NASA was maintained throughout the program to ensure that the model design would be appropriate for the intended purpose. Emphasis throughout the design and fabrication program was on obtaining and operationally suitable model at minimum cost. Design, construction, checkout and delivery of the model were the responsibility of the contractor, and were completed on schedule.

REQUIREMENTS

The requirements adopted for the model may be divided into three catagories: design, environmental, and operational. Some were fundamentally necessary, some were dictated by the intended purpose of the model, and some were arbitrarily selected for practical considerations. A listing by category, along with pertinent comments regarding their philosophy and implications, is presented in the following paragraphs.

Design Requirements

All primary structural and functional parts were constructed of metal as specifically requested by NASA. Increased durability and dimensional stability of metal construction were considered to justify higher cost.

External geometry of the hub, spokes, and rim modules was designed to scale. This was considered necessary for the demonstration of physical clearances.

Primary kinematics — hinge locations and travels — were designed to scale. Preliminary investigation showed this was possible if weights were not allowed to become excessive, and it is obviously desirable for the intended purpose of the model.

Internal structure and mechanical elements were not designed to scale, but were applicable in principal to full-scale design where practical. The preliminary status of the full-scale design, plus environmental differences and scaling effects, dictate this requirement.

A minimum ultimate strength safety factor of two was established. This was arbitrarily chosen as a suitable margin of safety.

Environmental Requirements

The model must operate under normal gravity environment. Although undesirably different from the zero-gravity deployment requirement of the full-scale space station, this is obviously required for the model as conceived.

The model must operate at room temperatures and pressures. Demonstration or testing of temperature extremes, vacuum, or corpuscular conditions of space were not, by definition, within the scope of the model program. Intended use of the model by NASA was limited to indoor laboratory conditions.

Operational Requirements

The model is required to be self-deploying and self-folding, with single-point overhead suspension. NASA agreed this manner of operation was best suited to the intended purposes of the model. External "puppet" cables to minimize actuation requirements and partially compensate gravity would benefit the actuation system design, but would result in reduced demonstration value.

Operating time must be reasonable. The main considerations were actuation requirements and use of the model for demonstration. Excessively long cycle times would likely detract from the demonstration value; excessively short times would result in a highly impractical actuation system requirement. Preliminary investigations resulted in acceptance of a range of 1 to 5 minutes as reasonable; the final choice was 2 minutes. An operating time for the full-scale station has not been established, but cycle times as long as 30 minutes might prove optimum. From the standpoint of visual similarity, time scaling proportional to dimensional scaling would apply.

No sealing, locking, pressurization, or dynamic (spin) provisions are required. These aspects of the full-scale station were, by definition, outside the scope of the model program.

ANALYSIS

A general analysis of the kinematics involved and the actuations required is presented below. Detailed analysis of the systems employed is included in the section on design.

Kinematics

The kinematics of the concept involves five sets of articulations: the rim-hinge rotations (twelve); the spoke inboard-hinge rotations (three); the spoke outboard-hinge rotations (three); the spoke-to-rim swivels (three); and the spoke extensions (three). The first four sets comprise two kinematic identities — that is, the rim-hinge rotations and spoke-to-rim swivels have identical in-phase motions, and the spoke inboard and outboard hinges have identical in-phase motions. Thus, there are only three independent motions involved in the kinematics:

1. The rim-module rotation

2. The spoke rotation

3. The spoke extension

Quantitative insight into the relationship between these three motions can be obtained by relating them to the travel of a common point in the system. Because the rim-element ring and the spoke cluster are recognizably two separate physical structures, the interconnecting point between them (the spoke outboard-hinge point) is a logical choice. (Only a one-third segment need be considered, as the kinematics is hexagonally antisymmetrical.) The condition of identity is the horizontal travel of this point from the center line.

In defining the relationship of the three basic motions, three geometric anomalies of the system must be noted:

1. The kinematic center lines of the spoke and rim modules (lines between hinges) are not parallel to their goemetric center lines. Thus, although the geometric center line travels are 0 to $\pi/2$ functions, the kinematic center lines are not.

2. The kinematic center line travels of the spoke and rim modules are out of phase with each other by approximately 11.1 degrees. The rim motion is leading.

3. The spoke extension motion is along its geometric, rather than kinematic, center lines.

The resulting functions necessary to define the three motions are these:

d = horizontal travel of spoke - rim joint

α = Rim geometrical - center lines angle from vertical

α' = Rim kinematic - center lines angle from vertical

B = Spoke geometrical - center lines angle from vertical

B' = Spoke kinematic - center lines angle from vertical

e = Spoke extension

e_h = horizontal component of spoke extension

Plots of α, B, and e v.s. d for the two extreme modes of spoke angle extension are shown in Figure 11; plots for the special intermediate case of spoke and rim angles equal are shown in Figure 12.

From an examination of these plots, the relationships are seen to be generally nonlinear, but with one degree of freedom which permits an arbitrary variation of their relationship, such that, for one particular variation(Figure 12), the spoke and rim module rotations can be linear and equal.

Actuation

Synchronized actuation of at least one articulation of each of the three basic motions is necessary for self-deployment, which can be understood from the following considerations:

A condition of zero mechanical advantage of both the spoke rotation and telescoping motions over the rim rotation exists near the full deployed position, such that only actuation of rim hinges or rim-to-spoke swivels can complete the rim rotation motion.

A condition of zero mechanical advantage of the rim rotation and spoke telescoping motions over the spoke rotation is approached at the full deployed position, such that only actuation of the spoke inboard or outboard hinges can complete the spoke rotation motion.

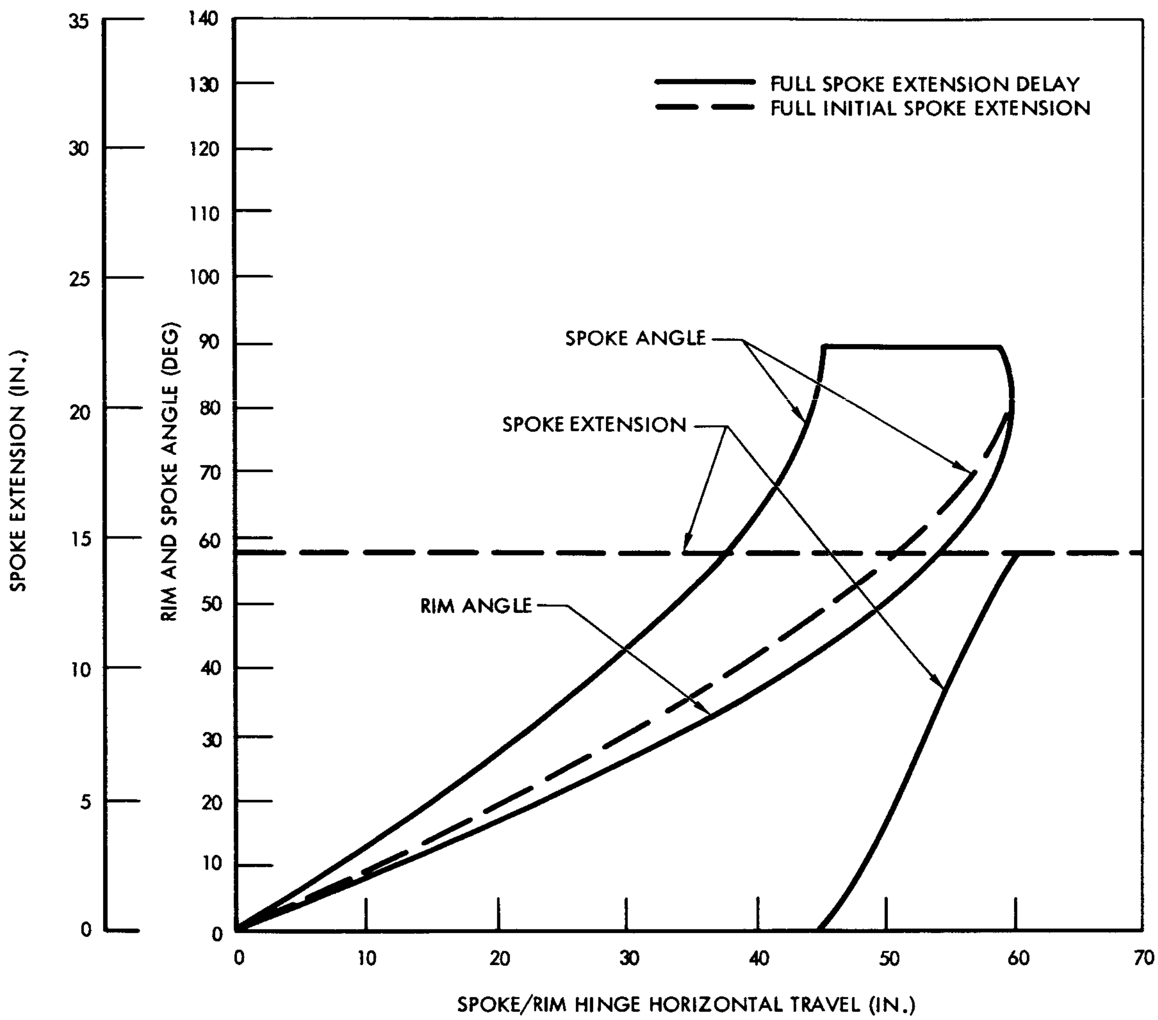


Figure 11. Rim Angle, Spoke Angle, and Spoke Extension Motion Kinematics - Extreme Modes

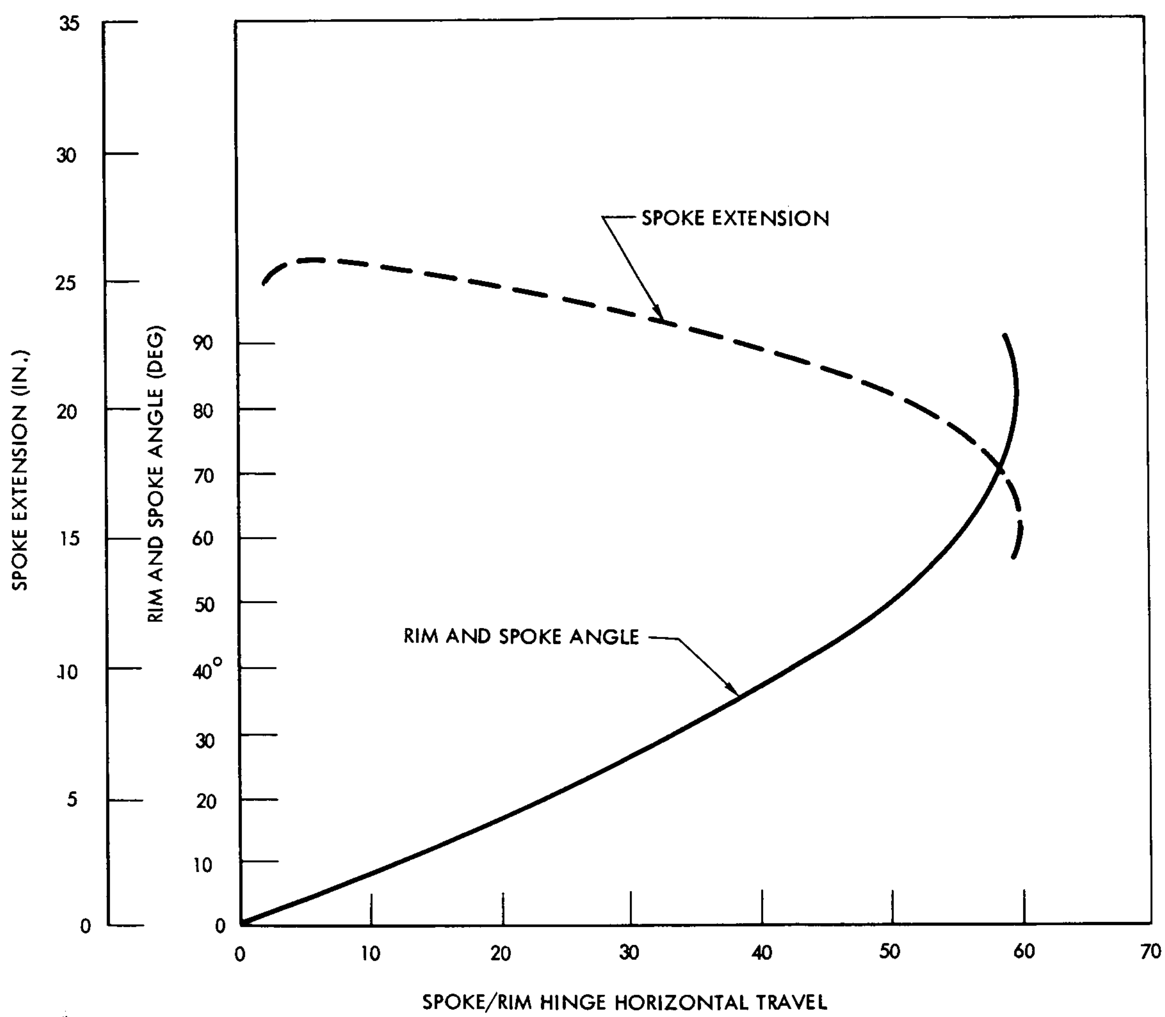


Figure 12. Rim Angle, Spoke Angle, and Spoke Extension Motion Kinematics-Equal Rim and Spoke Angles

A condition of zero mechanical advantage of the spoke rotation and rim rotation motions over the spoke extension exists at the fully retracted position, such that only by actuation of the spoke extension can its motion be controlled.

Internal instability of the six rim modules due to torsional freedom inherent in the hinge link system requires that the rim module hinge articulations (or alternately, the three rim-to-spoke swivel articulations) be synchronized in all positions. If synchronization of the rim-to-spoke swivels were employed, synchronization of the spoke outboard hinges near the retracted position would be required for complete stability.

Relatively low equalizing leverage is evident for both the spoke-rotation and spoke-extension motions in all positions. Self-energized binding, below a critical threshold value, similar to the binding of a drawer, would result in stalling of the system, or structural failure. The critical threshold depends on the structural stiffness, articulation friction, and mechanical leverage of the system, and would be determined accurately only by actual test. The problem can be avoided by assuming the need of synchronization of these motions.

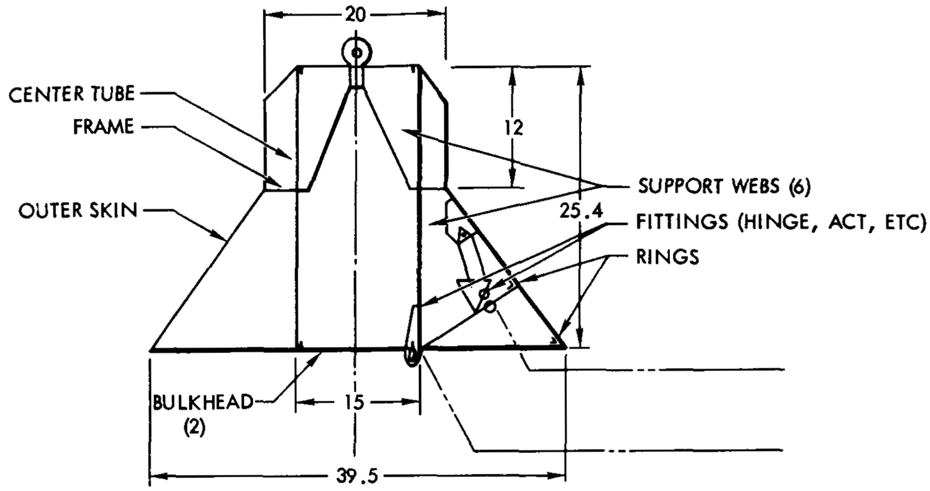
The actuation system selected for the model incorporates: synchronized actuation of all twelve rim hinges, synchronized actuation of the three inboard spoke hinges, positive control of the spoke extension from the retracted to approximately mid-deployment position, and synchronization of the spoke extension in all positions. From investigations to date, it is believed that this is also representative of the type of actuation provisions required in the full-scale station.

DESIGN

Significant aspects of the design procedure, including the important alternates considered, the designs selected, the reasons for selection, and supporting data, are presented in the following paragraphs.

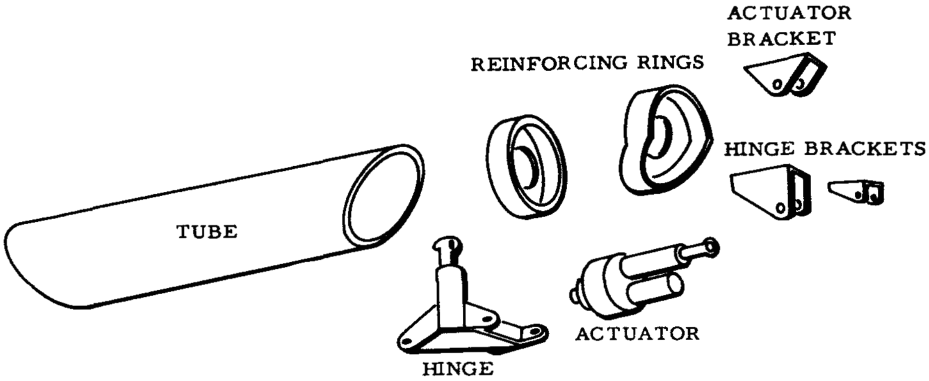
Structural and Mechanical

Initial iterations between types of structure, associated weight, and resulting actuator loads were performed to establish a design base point. Simple thick-walled tube construction was discarded in favor of thin-walled monocoque design because of excessive spoke actuator loads. The selected base point structure and weight breakdown are shown in Figures 13, 14, and 15.



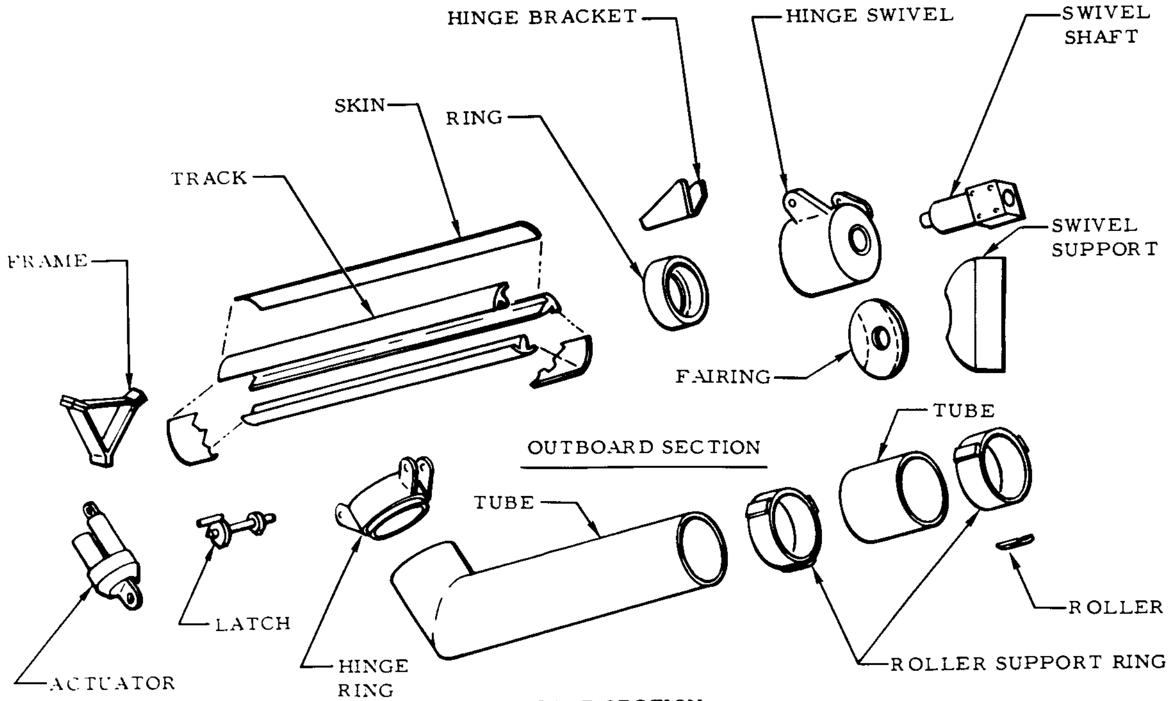
ITEM	POUND WEIGHT
CENTER TUBE (0.032 AL) 0.032 X 15 X π X 25.4 X 0.1 =	3.8
OUTER SKIN (0.032 AL) 0.032 X (30 X π X 13.4 + 20 X π X 12) X 0.1 =	5.8
SUPPORT WEBS (0.032 AL) 0.032 X (8 X 12 + 9 X 6) X 0.1 X 6 =	2.9
FRAME (0.040 AL) 0.040 X 5 X 17.5 X π X 0.1 =	1.1
BULKHEAD (2) (0.032 AL) 0.032 X 8.2^2 X π X 0.1 X 2 =	1.4
RINGS (0.1 AL ANGLES) 0.1 X 1.5 X 72 X π X 0.1 =	4.0
FITTINGS (13 @ 0.35 LB EA)	4.5
MISCELLANEOUS (STIFFENERS, ETC)	5.0
TOTAL	28.5

Figure 13. Preliminary Weight Estimate - Hub



ITEM	WEIGHT (LB)
TUBE (0.032 ALUM.) 12 X π X 82.5 X 0.032 X 0.1	10.0
RINGS (0.125 X 0.8 X 0.8 ANGLES) (4) 0.125 X 1.5 X 11.5 X π X 0.1 X 4	2.7
ACTUATOR BRACKET (0.18 ALUM. CHANNEL) (2) 0.18 X 3 X 6 X 0.1 X 2	0.7
HINGE BRACKETS (0.18 ALUM. CHANNEL) (2) 0.18 X 7 X 6 X 0.1 X 2	1.5
HINGE (ALUM. WELDMENT) 0.18 X 4 X 3 X 0.1 = 0.22 0.4 X 1 X 7 X 0.1 = 0.28 0.5 X 0.75 X 2.5 X 0.1 = 0.10 0.25 X 2 X 3 X 0.1 = 0.15 0.1 X 4.5 X 4.2 X 0.1 = 0.19 SUBTOTAL	1.0
ACTUATOR (2) 0.8^2 X π X 3 X 0.1 = 0.60 0.8^2 X π X 3.5 X 0.3 = 2.10 0.5^2 X π X 5 X 0.3 = 1.20 SUBTOTAL 3.9 X 2	7.8
TOTAL SEGMENT WEIGHT	23.7

Figure 14. Preliminary Weight Estimate - Module



ITEM	POUND WEIGHT
OUTBOARD SECTION	
SKIN (3) (0.040 ALUM.) $6 \times \pi \times 30.5 \times 0.040 \times 0.1$	2.3
TRACK (3) (0.1 TEE) $0.1 \times 2.3 \times 28 \times 0.1 \times 3$	1.9
FRAME (6) (0.1 STRIP) $0.1 \times 0.8 \times 12 \times 0.1 \times 6$	0.6
RING (2) ($0.1 \times 0.8 \times 0.8$ ANGLE) $0.1 \times 1.5 \times 4.7 \times \pi \times 0.1 \times 2$	0.5
HINGE BRACKET (2) (0.15 ALUM.) $0.15 \times 3 \times 3 \times 0.1 \times 2$	0.3
HINGE SWIVEL (ALUM.) $1.25^2 \times \pi \times 0.1$	2.0
SWIVEL SHAFT (STEEL) $(0.125 \times 1.4 \times \pi \times 4) + (2 \times 2 \times 2.2 - 0.75^2 \times \pi \times 2.2) \times 0.3$	2.0
SWIVEL SUPPORT (ALUM.) $0.063 \times 5 \times 6 \times 0.1$	0.2
FAIRING (ALUM.) $0.063 \times 3^2 \times \pi \times 0.1$	0.2
SUBTOTAL	10.0
INBOARD SECTION	
TUBES (0.06 ALUM.) $0.06 \times 6 \times \pi \times 35 \times 0.1$	4.0
HINGE RING (0.10 ALUM.) $0.10 \times (6 \times \pi + 9) \times 4.0 \times 0.1$	1.1
LATCH $0.8 \times 1.7 \times 0.7 \times 2 \times 0.1 + 0.1 \times 0.4 \times \pi \times 6.3 \times 0.3$	0.5
ACTUATOR (SAME AS RIM HINGE)	3.9
ROLLER SUPPORT RING (STEEL) (2) $0.25 \times 5.8 \times \pi \times 2.5 \times 0.3 \times 2$	6.8
ROLLER (6)(ALUM.) $0.3 \times 2.5 \times 1.5 \times 0.1 \times 6$	0.8
SUBTOTAL	17.1
TOTAL SPOKE (EACH)	27.1

Figure 15. Preliminary Weight Estimate - Spoke

Various methods of actuation were considered. Individual hydraulic actuators were rejected because of the obvious synchronization problems. Mechanically driven actuation from a central motor (through cables or shafting) was investigated, and although apparently suitable for the model, was rejected because of doubtful applicability to the full-size system. A system employing rotary, epicyclic, gear-type actuators, which are electrically driven and frequency controlled, appears to be the most suitable for the full-size station. The actuators would be mounted integrally in the spoke and rim hinges, and would drive the spoke extension through rack and pinions.

This system provides light, compact, and structurally simple actuation, with the means to accommodate the nonlinear synchronization relationship between the three basic motions (Figures 11 and 12). Ideally, the kinematic mode of Figure 12 would be employed, where the gearing between rim and spoke motions is linear and unity; thus, only the spoke extension motion would require programmed synchronization. For the model, however, rotary type actuators were found to be too large for the space available, due to scaling effects and difference in load conditions (1 g). Also, development of a frequency-controlled system was considered to be beyond the scope of the program.

Electrically driven linear (screwjack) type actuators were investigated and appeared to be feasible for the model loads and available space at the rim and spoke hinges. By proper arrangement of the actuator kinematics, linear and unity gearing between the two sets of actuators was possible, such that identical actuators could be used, with synchronization by means of constant-frequency, phase-locked (zero slip) a-c motors. For the nonlinear spoke-extension motion, a cable feed-out system, driven from the spoke motion, and capable of positive control of spoke extension through the critical (near stowed) part of the cycle, was worked out.

By connecting the cables from each spoke to a common spring loaded carriage, equalization and take-up of differential motion at the non-critical (near deployed) part of the cycle were found to be possible. Further studies disclosed no discrepancies in the suitability of the two systems to perform the required actuation functions, and revealed no better solution, so they were adopted as the systems to be used. As finally refined, the detailed kinematics of the actuators and cable feedout pulleys are as shown in Figure 16.

The resulting rim rotation, spoke rotation, and spoke extension motions, along with the cable feedout and spring takeup motions plotted against actuator travel, are shown in Figure 17. Figure 18 shows the take-up spring characteristics. Calculations of these motions are

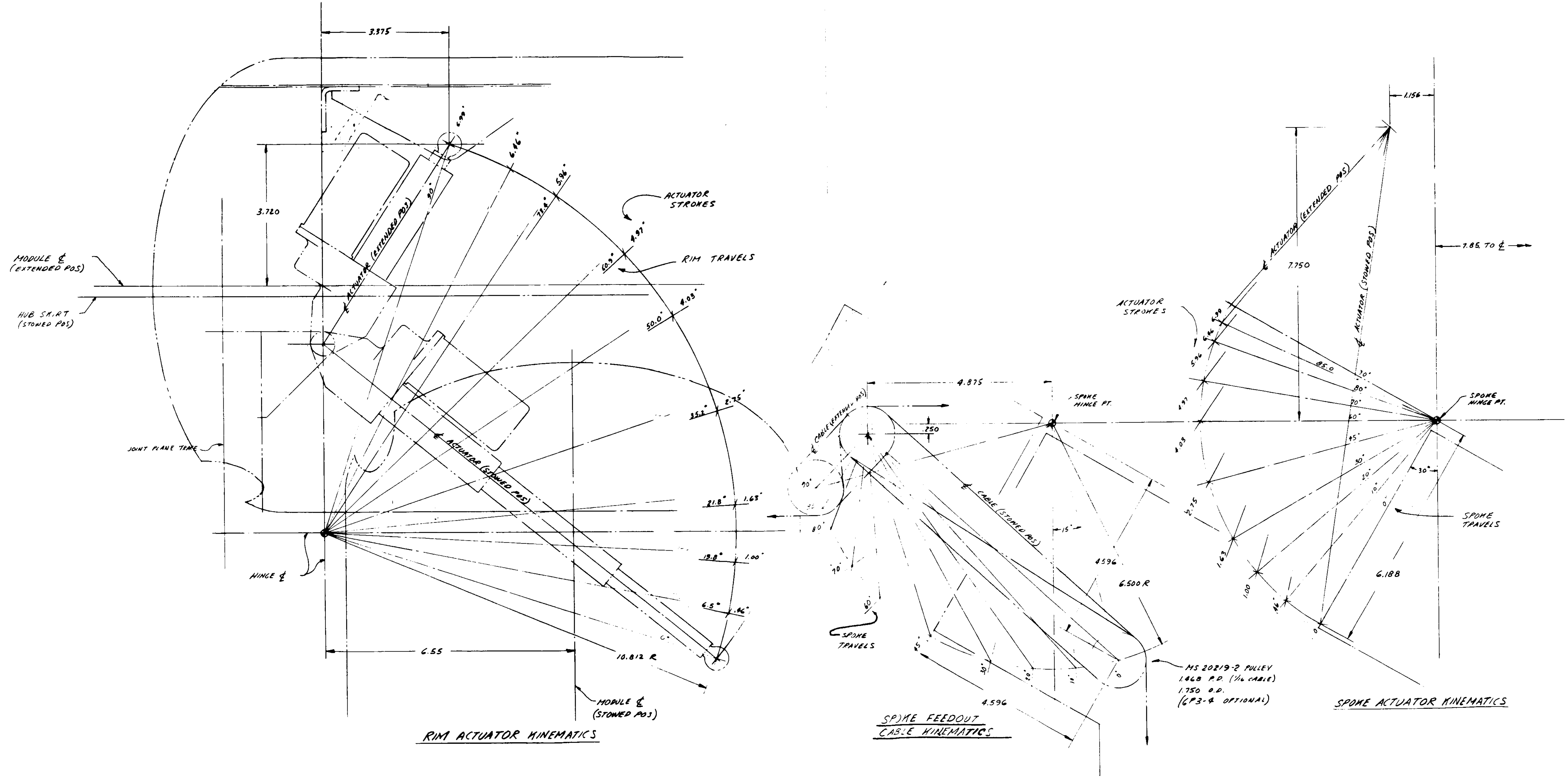
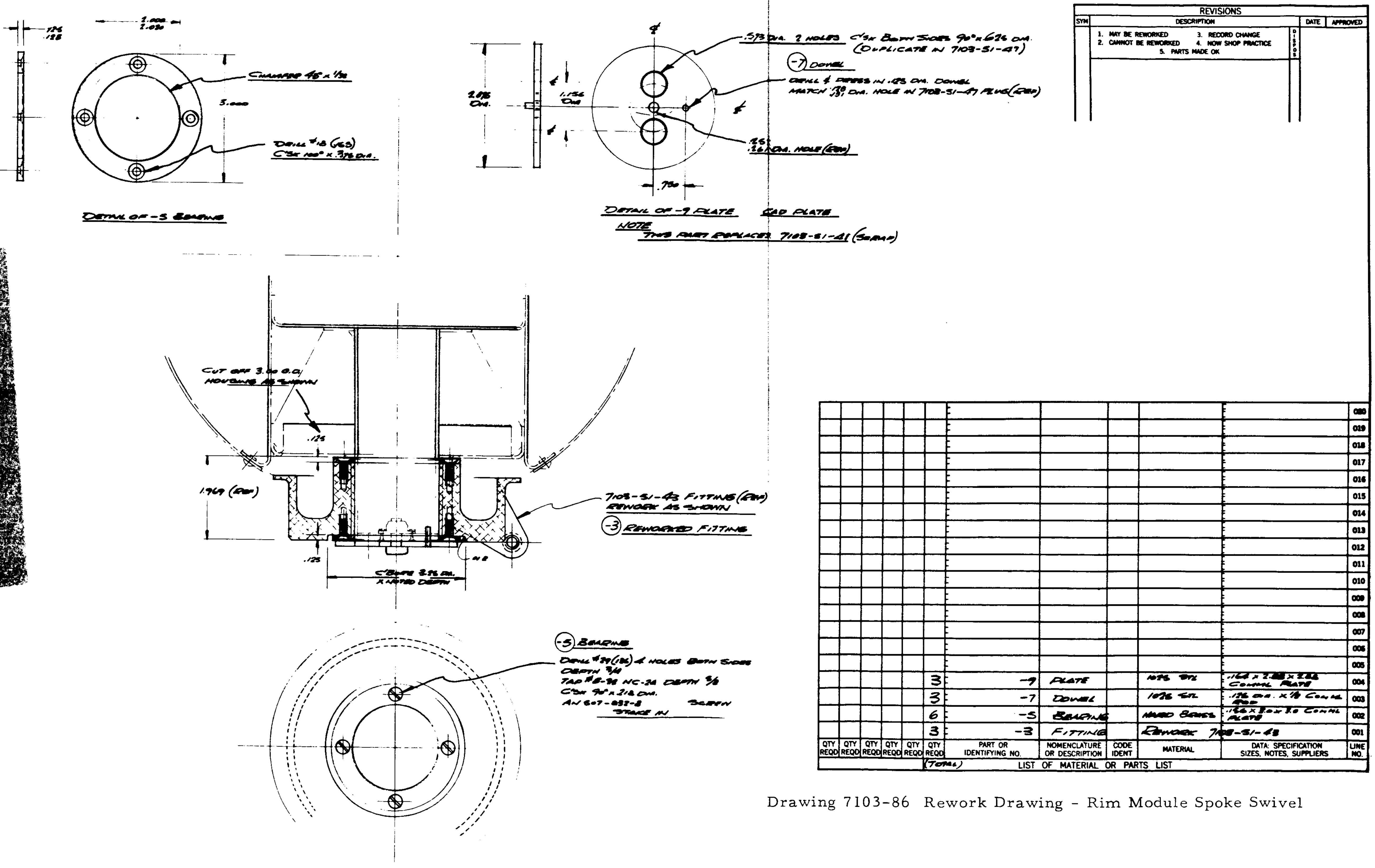
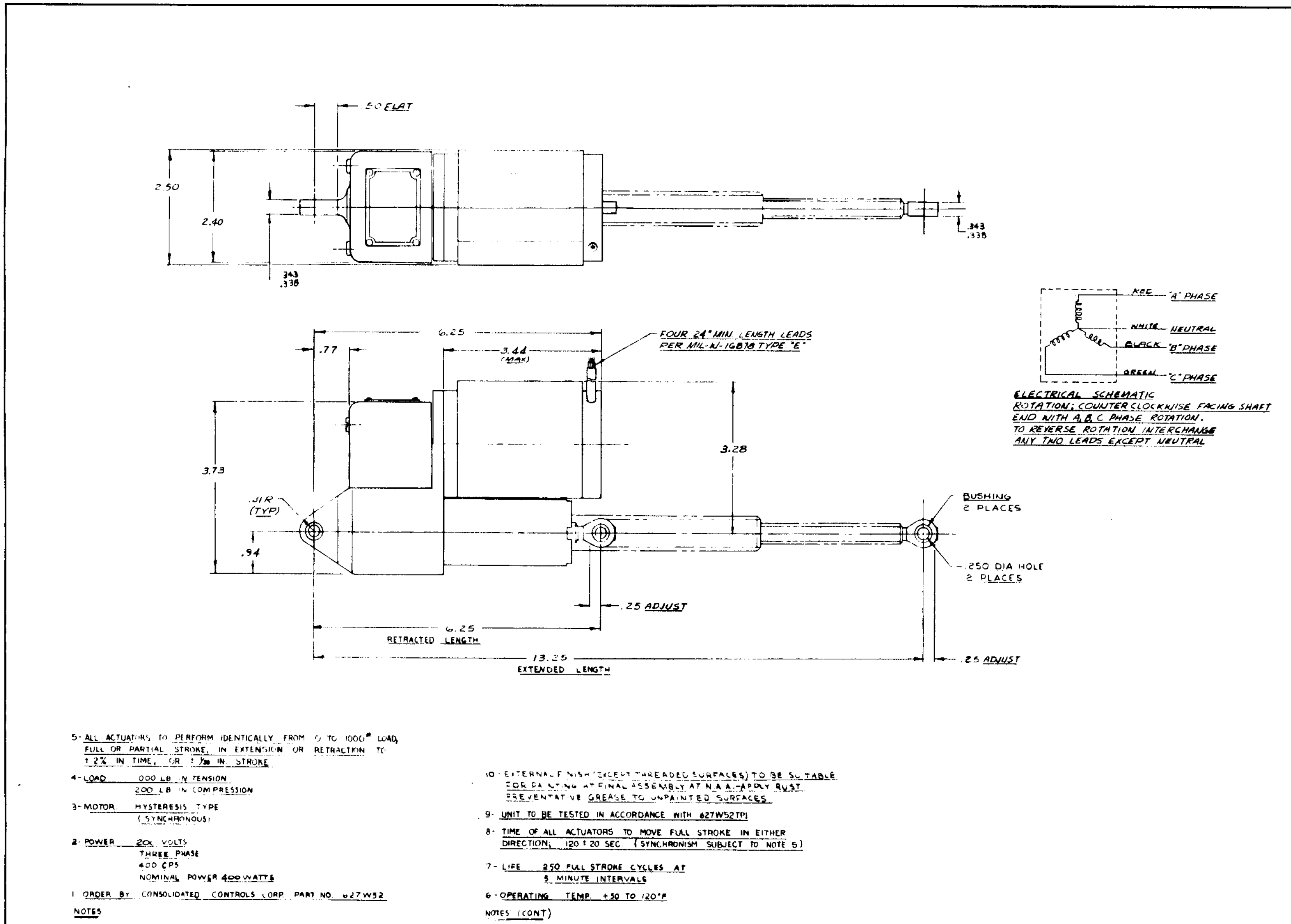


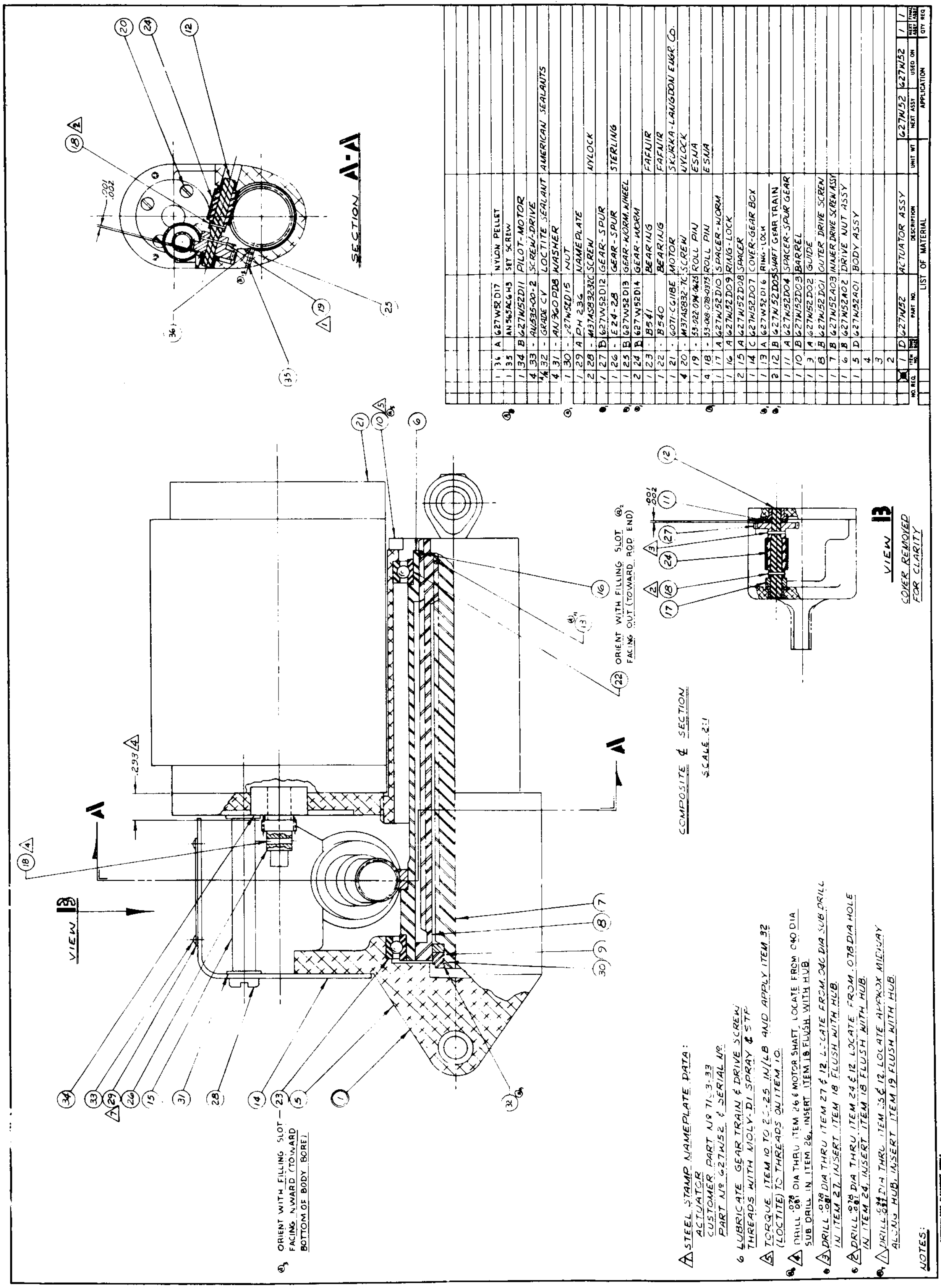
Figure 16. SDSS Detailed Actuation Kinematics



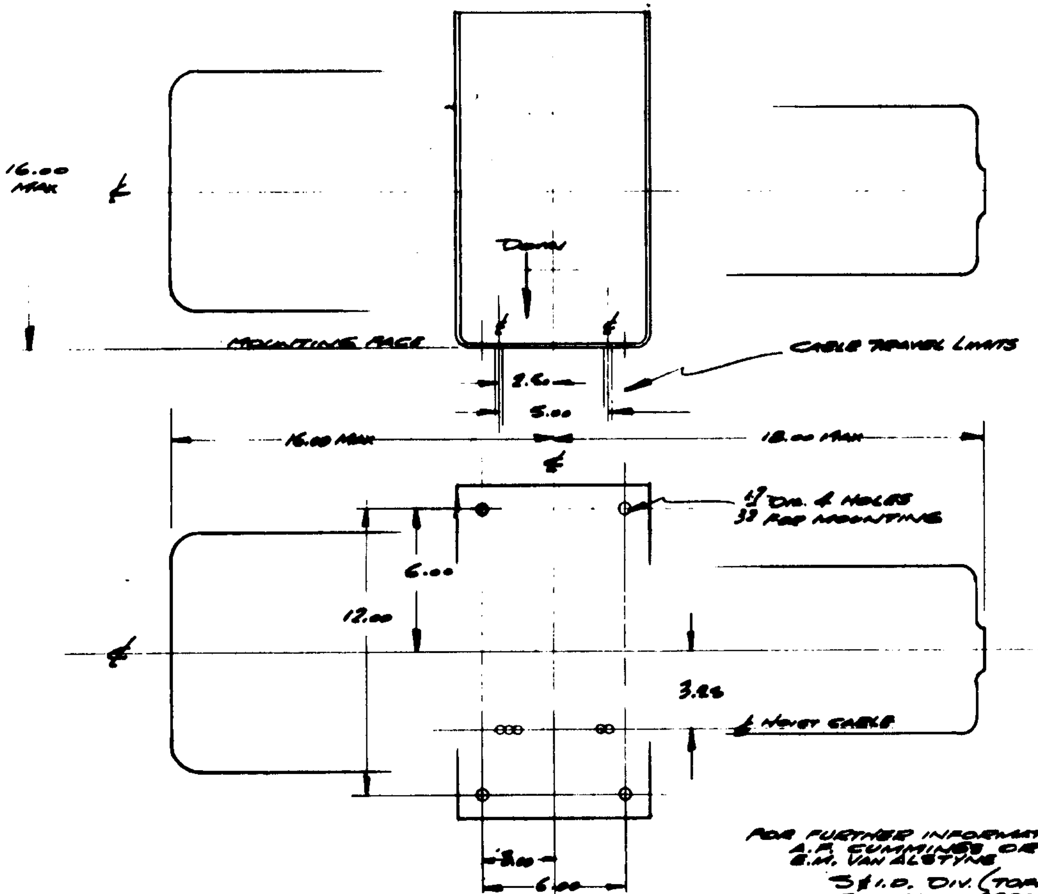
Drawing 7103-86 Rework Drawing - Rim Module Spoke Swivel



Drawing 627W-52 Actuator - Linear Electrical (Outline)



Drawing 627W-52A Actuator - Linear Electrical (Detailed)



SPECIFICATIONS

MOTOR
220 V, 3 PHASE, 60 CYCLE

CONTROL
MOMENTARY CONTACT TWO STATION PUSH BUTTON CONTROL (DEAD MAN TYPE) WITH 19 FT OF FLEX CONTROL CABLE

UPPER POSITION LIMIT SWITCH

HOIST
CAPACITY 1000#
SINGLE LINE, 34 FT/MIN, SINGLE SPEED
15 FT OF 1/4 DIA. WIRE ROPE (6 x 37) WITH DEAD END FITTING & BOTTOM #4 SWAGED ON SAFETY HOOK

MAY BE PURCHASED FROM
WRIGHT HOIST DIVISION OF AMER. CHAIN & CABLE CO.
8800 E ACCO ST. LOS ANGELES

FOR FURTHER INFORMATION CALL
A.F. CUMMINGS OR
E.M. VAN ALSTYNE
S&I.D. DIV. (TORCE 1281)
EXT. 6858, 6859.

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA: SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
											005
											004
											003
											002
											001

LIST OF MATERIAL OR PARTS LIST

Drawing 7103-90 Specification Drawing - Base Mounted Hoist

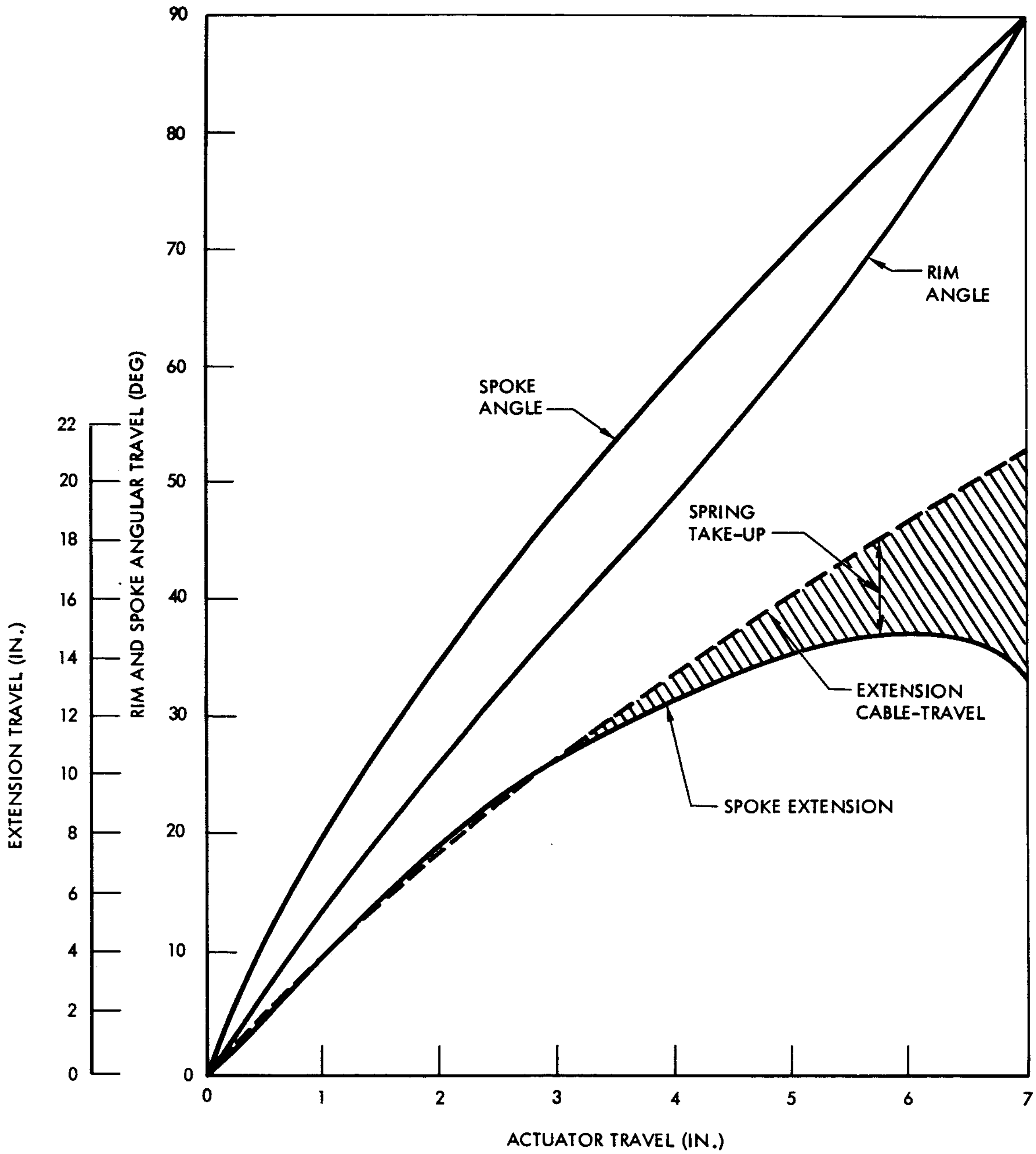


Figure 17. Rim Angle, Spoke Angle, and Spoke Extension Versus Actuator Travel

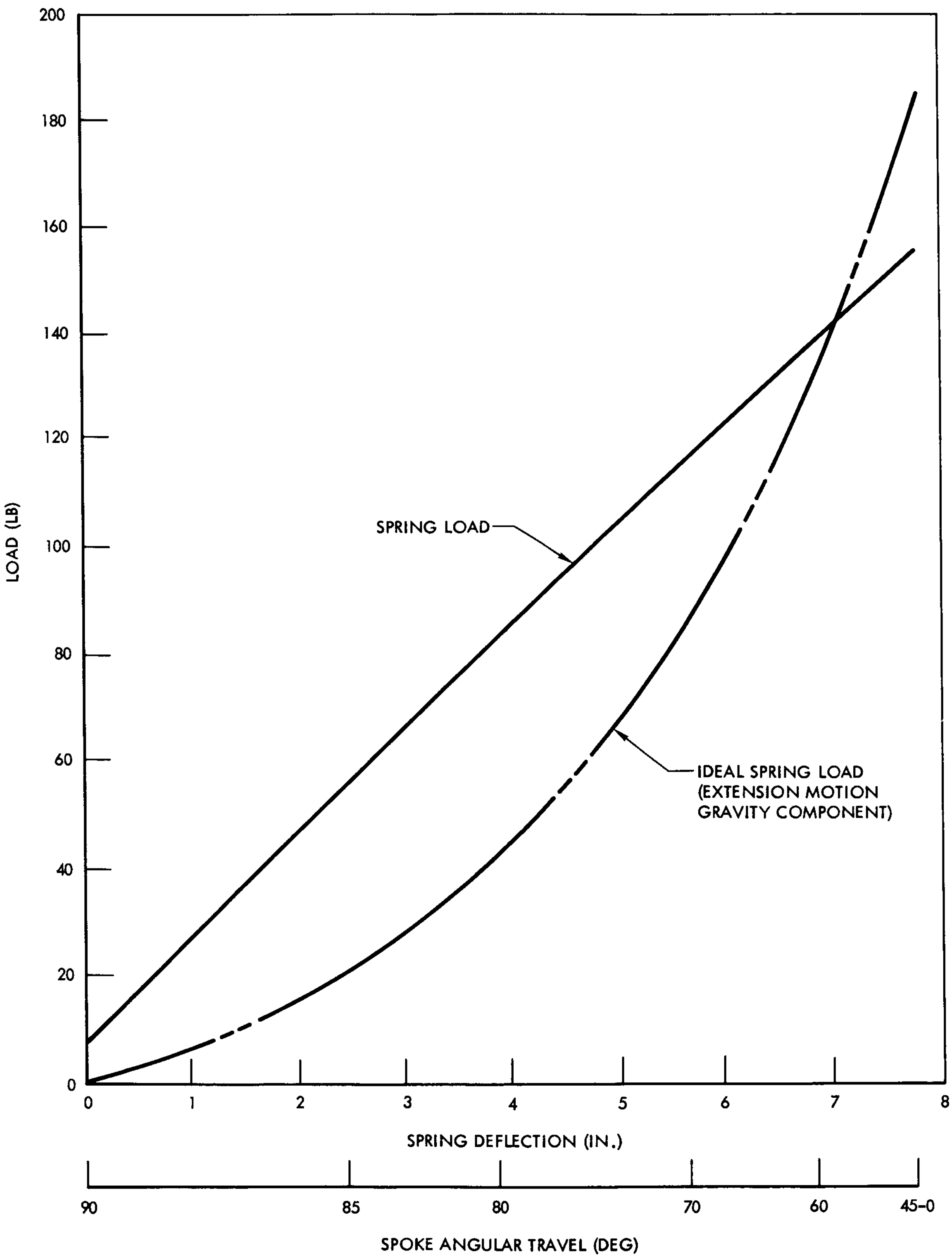


Figure 18. Extension Cable Takeup Spring Characteristics

presented for reference in Figures 19 and 20. Figure 21 shows the over-all kinematics and tabulates the actuation loads at intervals through the travel. Final physical details of the actuation system are as depicted in the working drawings.

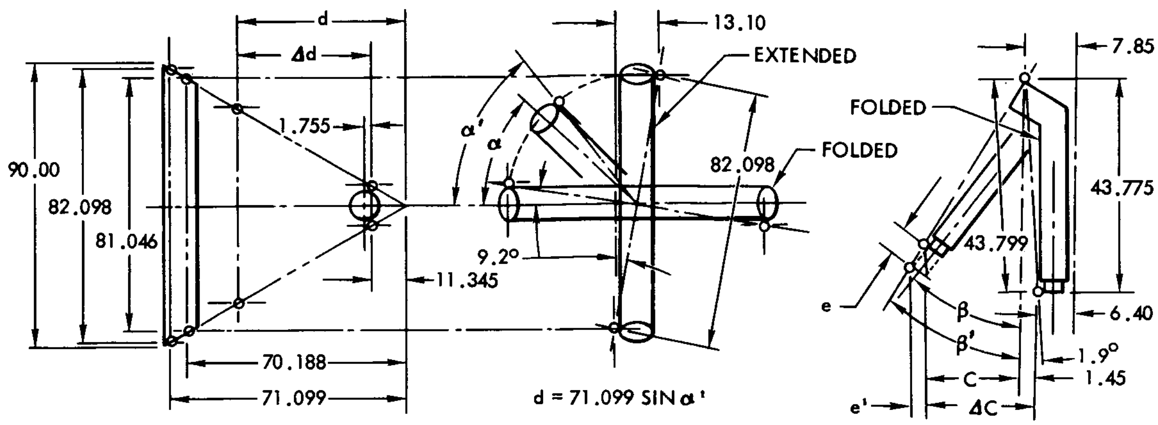
A counter-balancing system to offset high spoke actuator loads resulting from the effects of gravity was recognized to be desirable. Counterbalancing of the gravity effects is also desirable from the standpoint of closer simulation of gravity-free deployment of a real station. A cable system, contained within the envelope of the hub, and utilizing the model's own weight for the balancing function, was devised and incorporated in the model design.

The cable system supports the model at a point on each spoke, with the rim mass outboard counterbalanced by the hub mass inboard, so that, in principal, the spokes become balanced beams. Loads, with and without this system for a range of hub weights are included in Figure 21 for comparison. Optimum counterbalancing is seen to require a relatively high hub-weight.

As a result of the counterbalancing requirement, minimal hub weight was not an important factor in the design. Advantage was taken of this circumstance by building the basic hub of a "boiler plate" construction, resulting in minimum cost and complexity, and maximum accessibility to the mechanism it houses. External hub geometry is provided by a readily removable non-structural cover.

Design of the spoke and rim hinges, and the spoke to rim swivel, did not present any particular problems. Loads are small, with hinge-pin sizes being selected by practical considerations, rather than their strength. Plain bearings are used, with the provisions of replaceable bushings, if wear should prove a factor. Fittings, machined for accuracy, are generally of aluminum for minimum weight. A post to attach the actuators and provide equalized motion of each joint about its two hinges is required on the rim hinge-link.

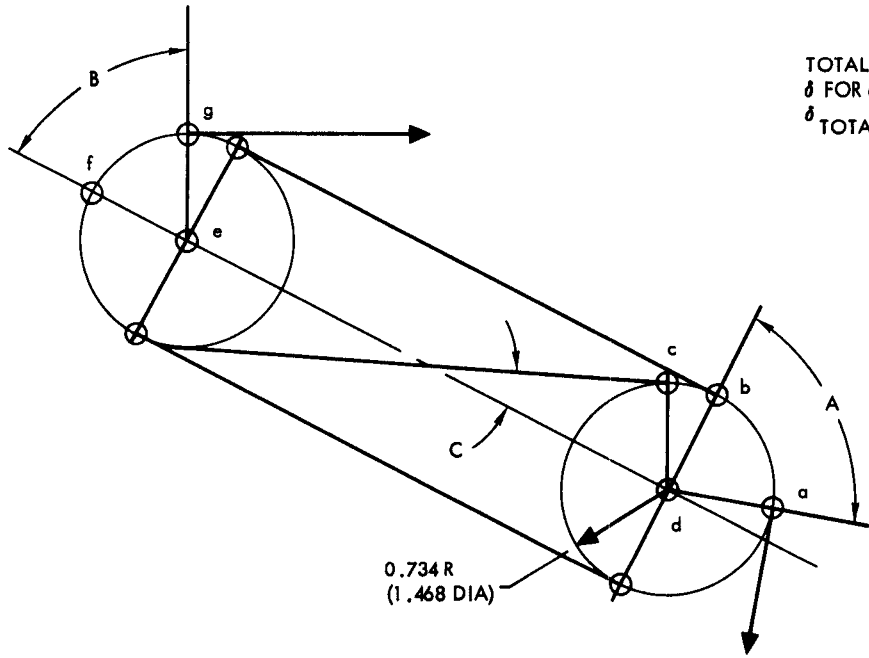
The spoke extension is guided by two sets of three rollers, mounted on the inboard (outer) spoke section, and running in three tracks on the outboard (inner) spoke section. The splined action provided by the tracks is necessary to the deployment kinematics. The tracks are provided in a simple manner by six strips riveted to the basic spoke tube. The rollers are mounted in six identical fittings, so arranged as to be adjustable in and out by shimming, for good fit. This arrangement provides for an internally accessible seal design and is considered representative of the system required on the full scale station.



α	α'	d	Δd	β	β'	C	ΔC	e'	e
0°	9.2°	11.345	0	0°	-1.9°	-1.450	0	0	0
6.5	15.7°	19.239	7.894	10°	8.1°	6.171	7.621	0.273	1.572
13.8	23.0°	27.781	16.436	20°	18.1°	13.607	15.057	1.379	4.032
21.8	31.0°	36.619	25.274	30°	28.1°	20.630	22.080	3.194	6.388
35.2	44.4°	49.745	38.400	45°	43.1°	29.927	31.377	7.023	9.932
50.0	59.2°	61.071	49.726	60°	58.1°	37.184	38.634	11.092	12.808
60.9	70.1°	66.854	55.509	70°	68.1°	40.638	42.088	13.421	14.282
73.4	82.6°	70.507	59.162	80°	78.1°	42.858	44.308	14.854	15.083
90°	99.2°	70.188	58.843	90°	88.1°	43.775	45.225	13.618	13.618
80.8°	90.0°	71.099	59.754	85.0°	83.1°	43.482	44.932	14.822	14.879

Figure 19. Spoke/Rim Kinematics

TOTAL CABLE LENGTH ≅ 80 IN.
δ FOR 67 LB LOAD = 0.003 LB/IN.
δ_{TOTAL} = 80 X 0.003 = 0.240 IN.



SPOKE GEOM ℄ ANGLE
(0 = STOWED POSITION)

POS	A	B	C	(d - e)	3(d - e)	(a - b)	(f - g)	(b - c)	TOTAL VAR LENGTH	TOTAL SLACK WITH DEFLECTION	SPOKE TRAVEL (REF)	NET SLACK WITH DEFLECTION
0°	47.5°	47.5°	9.4°	8.90	26.70	0.61	0.61	0.12	28.04	0	0	0
10°	51.2	41.2°	10.1°	8.27	24.81	0.66	0.55	0.13	26.15	1.88	1.57	0.31
20°	54.8	34.8°	11.0°	7.57	22.71	0.70	0.45	0.14	24.00	4.01	4.03	-0.02
30°	58.0	28.0°	12.2°	6.81	20.43	0.74	0.36	0.16	21.69	6.30	6.39	-0.09
45°	61.9	16.9°	14.7°	5.60	16.80	0.79	0.22	0.19	18.00	9.94	9.93	+0.01
60°	64.0	4.0°	18.7°	4.35	13.05	0.82	0.05	0.24	14.16	13.75	12.81	0.94
70°	63.0	-7.0°	22.8°	3.50	10.50	0.81	-0.09	0.29	11.51	16.39	14.28	2.11
80°	58.2	-21.8°	28.8°	2.68	8.04	0.75	-0.28	0.37	8.88	18.98	15.08	3.90
85°												5.30
90°	45.6	-44.4°	36.5°	1.98	5.94	0.58	-0.57	0.47	6.42	21.37	13.62	7.75

Figure 20. Spoke Extension Cable Kinematics

Actuator requirements were determined and submitted to a subcontractor for detail design. Kinematic practical considerations dictated the use of identical actuators (spoke and rim hinges) at all locations. Maximum actuator load occurs at the spoke locations, being approximately 550 pounds tension for 500 pounds hub weight (Figure 11). Calculations indicate a maximum load in the order of 100 pounds axial force at the rim locations, if properly adjusted. No significant actuator compression loads were found to exist. Conservatively, 1000 pounds tension and 200 pounds compression were specified as the design operating loads. Trade offs between motor size and operating time resulted in a final operating selection of two minutes. The motor employed was found to require braking to maintain required synchronization, so dynamic braking has been incorporated. The final actuator design in drawing 627W52A, which is included in the appendix.

Electrical

The electric motor drive actuators and the control console are the major design consideration of the electrical system. The electric actuators were designed and fabricated by the Consolidated Controls Company, while the design and construction of the control console were achieved by the contractor.

Electrical Motor

The design requirements for the electrical motor driven actuators are discussed in the preceeding section. The characteristics of the resulting selected actuator motor are tabulated as follows:

Actual available space in the structure of the model elements placed certain limitations on minimum motor voltage. The 200-plus volt operating regime was selected to present a satisfactory motor envelope size for the great amount of work to be done. Motor data is as follows:

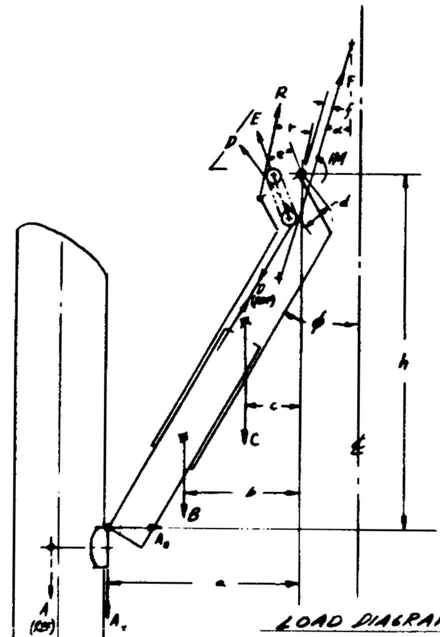
3ϕ, 4 wire, 400 cps

0.09 hp 50% eff

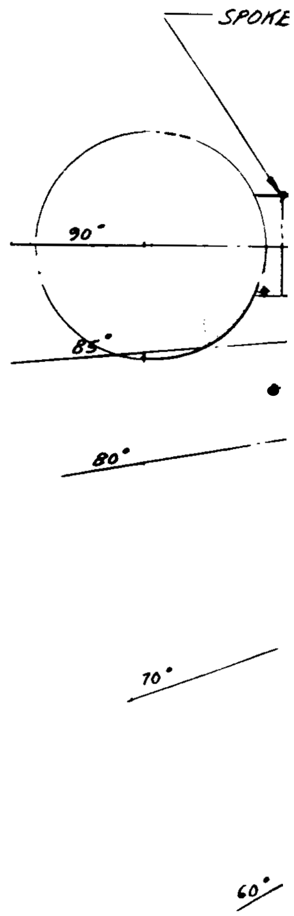
@ 200 volts line

ϕA = 1.1 amp, 41w	T = 4 oz in. start
ϕB = 1.08 amp, 39w	T = 3.92 oz in. run
ϕC = 1.08 amp, 38w	

line current = 2 amp start



LOAD DIAGRAM



WEIGHT BASIS

A - - - - - - - 78#		×3 = 234
SPOKE RIM - 35.5		
FREE RIM - 24.0		
LINK (2) - 4.1		
ACTUATOR(S) 14.4		
B - - - - - - - 8.5#		×3 = 26
O.B. SPOKE 8.36		
HARDWARE .14		
C (MID SPOKE) - - - 12.5#		×3 = 37
TOTAL WEIGHT LESS HUB		297#
HUB WEIGHT - - - VARIABLE*		

LOAD SUMMARY

φ	A_v	a	HM_{A_v}	A_o	h	HM_{A_o}	B	b	HM_B	C	c	HM_c	D	d	HM_D	E	e	HM_E	HM_{NET} (w/o F)	r
0°	78.0	-1.5	-117	0	43.8	-	8.5	-4.2	-36	12.5	-2.2	-27	86.5	3.63	-315	172	3.50	-602	-1097	2.28
10°	↑	+6.4	+500	0	44.9	-	↑	+1.1	+9	↑	+1.5	+19	85.0	4.00	-340	170	3.85	-655	-467	2.85
20°		14.9	1160	0	45.3	-		7.2	61		5.0	62	81.5	4.32	-353	163	4.16	-680	+250	3.37
30°		23.8	1860	0	44.0	-		13.8	118		8.4	105	75.0	4.63	-347	150	4.43	-665	1071	3.89
45°		36.9	2880	+72.7	38.8	~~[illegible]~~		24.1	206		13.0	162	[illegible]	5.02	[illegible]	[illegible]	4.74	[illegible]	[illegible]	4.50
60°		48.2	3760	-2.1	29.4	-62		33.6	286		16.8	210	46.0	5.32	-240	90	4.89	-440	3576	5.19
70°		54.0	4210	-8.5	21.1	-179		38.7	330		18.6	232	37.5	5.47	-205	75	4.80	-360	4028	5.54
80°		57.7	4500	-11.6	11.5	-134		42.1	358		19.9	249	26.5	5.58	-148	53	4.42	-235	4590	5.83
85°	↓	58.3	4550	-9.5	6.4	-61	↓	42.8	365	↓	20.3	254	17.0	5.61	-95	34	4.00	-136	4877	5.95
30°	78.0	57.3	4480	-1.7	1.35	-2	8.5	42.0	357	12.5	20.6	259	1.7	5.63	-10	3.4	3.30	-11	5073	6.05

*

φ	α	f	200 LB HUB (497 TOT) F	HM_F	HM_N	R	350 LB HUB (647 LB TOT) F	HM_F	HM_N	R	500 LB HUB (797 TOT) F	HM_F	HM_N	R
0	2.6	+4.7	166	+780	-317	-189	216	+1020	-77	-34	266	+1250	+153	+67
10	6.2	+3.3	167	+551	+84	+29	217	+719	+252	+88	267	+883	416	136
20	10.0	+1.9	169	+321	+571	170	220	+418	668	198	270	+513	763	226
30	13.6	+.5	171	+86	1157	297	223	+112	1183	305	274	+137	1208	311
45	19.1	-1.6	176	-281	[illegible]	[illegible]	229	-366	[illegible]	[illegible]	282	-451	[illegible]	[illegible]
60	24.2	-3.85	182	-700	2676	555	237	-913	2663	515	292	-1120	2456	475
70	27.0	-5.35	186	-990	3038	549	242	-1340	2728	490	299	-1600	2428	440
80	29.4	-6.25	190	-1300	3290	563	248	-1700	2890	495	305	-2090	2500	430
85	30.2	-7.65	194	-1480	3397	570	250	-1910	2967	500	308	-2350	2527	425
90	31.0	-8.4	195	-1640	3433	568	252	-2110	2965	490	311	-2610	2463	410

SPOKE ACTUATOR LOAD = R (REF)
+ = TENSION

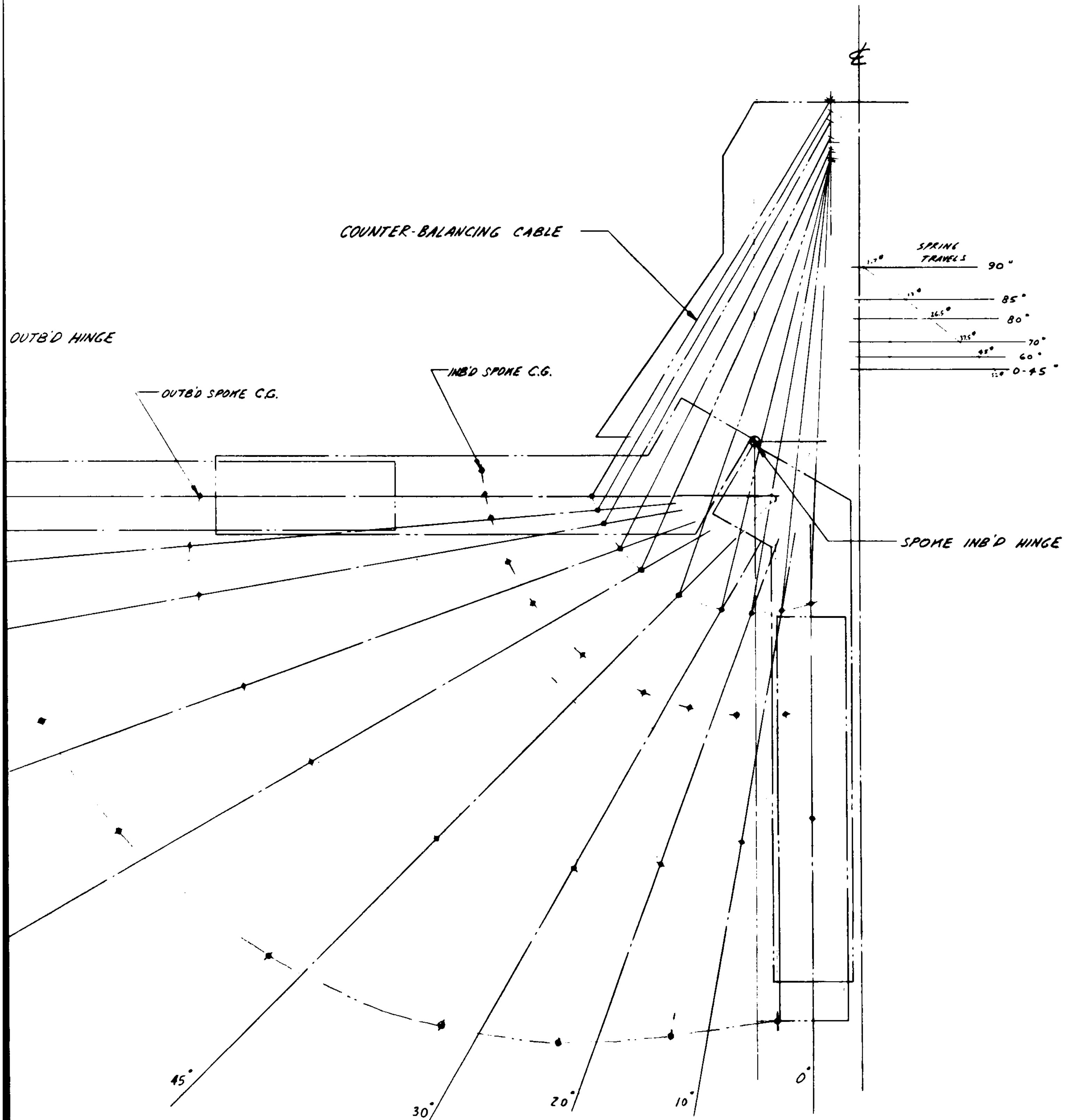


Figure 21. Overall Final Kinematics

powered from a d-c supply added within the contactor enclosure. (They were 60 ~, 208v solenoids. The modification was dictated by delivery schedule of a 400 ~ unit.) Eighty-three volts are developed across the filter capacitor until the deploy or retract relay is energized. There is then a drop to approximately fifty-four volts until the solenoid plunger moves sufficiently to break an auxiliary contact shunting a 90 Ω limiting resistor.

At this time the voltage drops again to about 25 where it remains until the control (deploy or retract) relay is deenergized. The limiting resistor maintains the wattage in the solenoid at a conservative level.

A neon lamp and a phase sensitive relay are connected between the circuit breaker and the contactor. The lamp indicates 3ϕ power is present, and the relay requires power on all three phases in the proper sequence and magnitude (±10 percent) to energize. If this relay does not energize, no dc relays can be energized. This ensures that source power will have the proper characteristics, i.e., prevents a possible phase reversal from driving the motors against limit switches which are not sensitive to that direction of travel.

The common of two twelve-volt batteries in series is connected to chassis or power ground together with the 3ϕ neutral line. Batteries were selected on the basis of availability, cost, and current capacity. Approximately 55 amperes are required for about two seconds during motor stopping.

The most negative terminal of the two batteries is the return for all the dc relays (including time delay relays). The most positive terminal is connected to the power switch. Closing the power switch applies twenty-four volts to a meter intended to give a rough indication of battery condition. The meter should never drop below twenty-two volts. An interlock jumper is connected from P 1-A to P 2-A to ensure that power cannot be routed to the model unless all circuits (especially limit) are closed.

If the power switch is closed, P_1 and P_2 are installed, and the phase sensitive relay is energized; the control switch is effective in the retract position. It is not effective in the deploy position until a lockout relay becomes energized. This is done by placing the control switch in the retract position until the model is fully retracted, and all time delay relays have relaxed (approximately two seconds after striking the respective limit switch). The advanced and retract relays determine whether the upper (deployed) limit or lower (retracted) limit switches will be energized, and it isolates them from each other.

Placing the control switch in the deploy position will allow current to pass through the contactor auxiliary contact, which prevents energizing a contactor solenoid until the other solenoid's plunger is clear of a mechanical interlock. (This feature is included for both deploy and retract). The current can continue through contacts of the lockout relay to the DEPLOY relay coil.

Once energized, the deploy relay latches in through its own contacts until either the control or power switch is turned off. Deploy relay contact applies power through the upper (deployed) limit switches to the control relay which in turn actuates the time-delay relay, then, drops out the lockout relay. Another set of deploy contacts energizes the F contactor solenoid which routes 3ϕ power to the energized-control relay and then to the motors. After approximately 2 minutes, the actuators have changed length i.e., become short enough to cause the switch to contact a striker which depresses the switch plunger. This actuates the switch and removes power from the control relay associated with that switch. Relaxing the control relay removes a-c power from the motor and dc power from the time delay associated with that control relay.

Although power has been removed from the time delay, the contacts will not relax for approximately two seconds. During this time 12 VCD is routed through the actuated time-delay contacts and through the relaxed-control relay contacts to the motor dc dynamic braking.

One battery is loaded with 8 motors and the other with 7. Twelve volts at about 6.55 amps should stop motor rotation in approximately one second. After all motors have stopped, returning the control switch to OFF will relax the deploy relay, which in turn, will remove power from the contactor solenoid. At this time the only battery drain is the dc meter and the phase-rotation, indicating lamp.

Diodes were added, where practical, across the relays and motors to reduce noise to other systems and to prolong contact life.

The required power source for operation of the control console is tabulated below:

220/115 VAC, 4 wire Y (star, 400 cycle per second, 10KVA minimum)

2 batteries each 12 VDC. Delco-571 or equivalent.

STRUCTURAL ANALYSIS

The 1/10 scale model of the space station is a functional unit to demonstrate the packaging and deployment concept of the full-size Self-Deploying Space Station. The model is designed to deploy and package automatically by use of fifteen mechanical actuators. There are two actuators at each module joint and three spoke actuators at the central hub. Two additional structural joints near the end of each module were incorporated into the design to provide for a change in the hinge and actuating system, in the event the installation of another system is desired.

The data in this section present an analysis of the loads developed on the model in a 1-g environment when oriented with the base of the hub parallel to the floor. Included are an analysis of the design-loads criteria, estimated component weights, a free-body diagram showing the applied loads and reactions and points of application, a summary of the loads calculated, and an analysis of the effect of adding ballast to the central hub.

DESIGN LOADS CRITERIA

The design loads for the model are developed by the spoke actuators lifting the modules at 1-g into their deployed position. The limit load on the components was determined by selecting an arbitrary load factor of 1.7 to account for dynamic effects. The sizes of the structural components were then determined by using a safety factor of 1.5 on limit load, and comparing stresses for the ultimate loads with the allowable ultimate strength of the material.

METHOD OF ANALYSIS

The loads analysis consists first in defining the kinematics geometry. This was determined from the three mechanisms comprising the spokes actuation, module actuation, and the telescoping spoke mechanism. All actuators are synchronized so they are of the same length at the same time during operation. The analysis was made by varying the spoke angles, θ, at 10° intervals and solving for the actuator lengths. From the actuator lengths, the rotation of the rim modules and the distances from the hub center line are determined. The telescoping effects of the spoke are now determined from the distances from the hub center line.

After the kinematics geometry is defined, the interacting loads may be determined. One-g conditions were used to develop the interacting loads.

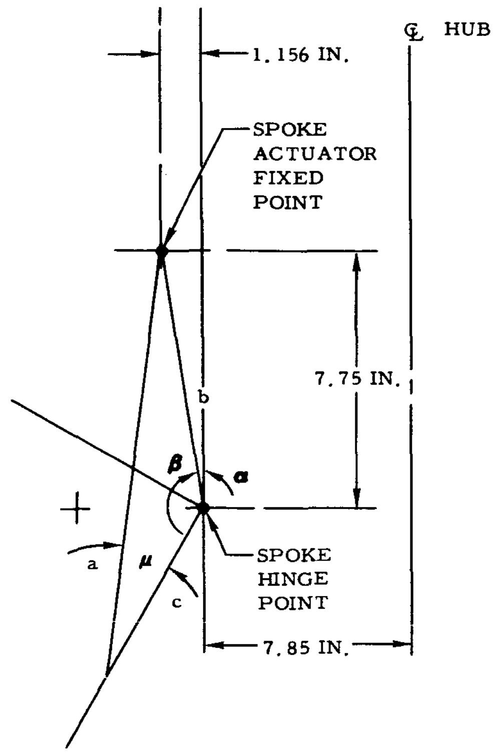
The ultimate loads are obtained by multiplying them by the ultimate load factor. Spoke and module actuator loads are determined by obtaining the summation of moments about the respective hinge points to produce static equilibrium. The inner spoke is supported on rollers fixed at the outer spoke in the fully deployed condition. When the model is packaged, suspension cables are provided to secure the rim modules and inner spoke to the spring at the central hub. The applied load from the modules are reacted by the normal component on the rollers and tension in the suspension cables. The equations used to develop the kinematic geometry of the spoke, module link actuating mechanism, and telescoping spoke mechanism are given on pages 41 through 46. The equations used to determine the interacting loads are developed on pages 46 through 50. The calculation of the geometric values and of the magnitude of the loads are presented in Tables 1 through 10.

WEIGHT STATEMENT

Estimated weights were used in determining the 1g static loading conditions. The estimated weight distribution to the spokes and modules is obtained from the following list.

Modules drawing Number	7103-51	178.65 lb	
Module links	7103-58	12.64 lb	
Module actuators (Assume 10 lb each)		120.00 lb	
	Module Wt		311.29 lb
Inner spoke wt	7103-12		25.08 lb
Outer spoke	7103-3	44.00 lb	
	7103-8	3.78	
	7103-17	2.94	
	Outer Spoke Wt		50.72 lb
Hub structure		270.32	
Hub actuators		30.00	
	Hub Wt		351.04 lb
	Total Weight		738.13 lb

SPOKE KINEMATIC GEOMETRY



$c = 6.188$

$b = \sqrt{\overline{7.75}^2 + \overline{1.156}^2} = 7.83$ IN.

α = ARC TAN. = 1.156/7.75

$\alpha = 8^\circ - 29$ FT

CONSIDERING THE INCREMENTAL
SPOKE ANGLE = $\theta = 0^\circ$ (FULLY DEPLOYED)

$\beta = 60 - \alpha + \theta$

$\beta = (51^\circ - 31 \text{ FT}) + \theta$

THUS THE ACTUATOR LENGTH MAY BE DETERMINED FROM THE TWO SIDES AND INCLUDED ANGLE OF THE OBLIQUE TRIANGLE BY USING THE LAW OF COSINES.

$a^2 = b^2 + c^2 - 2bc \cos \beta$

$a^2 = \overline{7.83}^2 + \overline{6.188}^2 - 2(7.83)6.188 \cos(\theta + 51^\circ - 31 \text{ FT})$

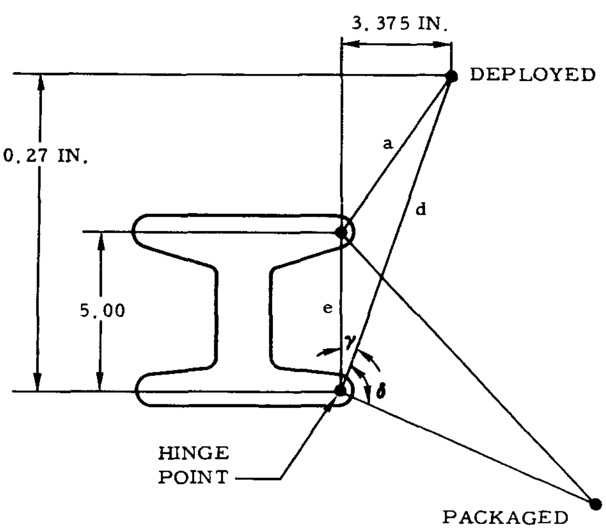
$a^2 = 99.72 - 96.8 \cos(\theta + 51^\circ - 31 \text{ FT})$

MODULE KINEMATIC GEOMETRY
LINK ACTUATOR MECHANISM

$d = \sqrt{\overline{10.27}^2 + \overline{3.375}^2}$
$d = 10.81$

γ = ARC TAN. $= \frac{3.375}{10.27}$

$\gamma = 18^\circ - 10'$ (DEPLOYED)



CONSIDERING THE INCREMENTAL
MODULE ANGLE = $\phi = 0$ (FULLY DEPLOYED)

$\delta = \delta + \phi$

$\delta = (18^\circ - 10') + \phi$

$a^2 = e^2 + d^2 - 2ed \cos \delta$

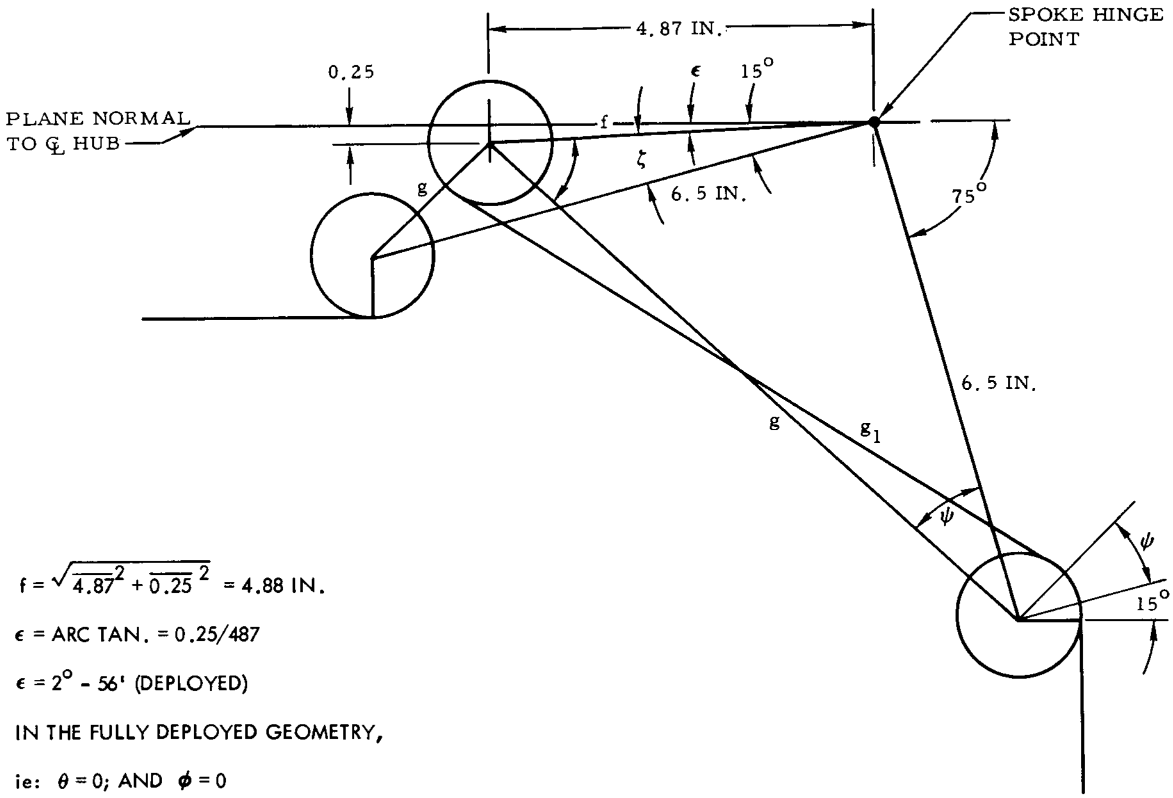
$$\cos\delta = \frac{e^2 + d^2 - a^2}{2ed} = \frac{\overline{5.0}^{\,2} + \overline{10.81}^{\,2} - a^2}{2(5.0)10.81}$$

$$\cos\delta = \frac{141.9 - a^2}{108.1}$$

$$\therefore \delta = \text{ARC COS} = \frac{141.9 - a^2}{108.1}$$

$$\phi = \delta - (18^\circ - 10\text{ FT})$$

MODULE KINEMATIC GEOMETRY
TELESCOPING SPOKE MECHANISM - A



$f = \sqrt{\overline{4.87}^2 + \overline{0.25}^{\,2}} = 4.88$ IN.

ϵ = ARC TAN. = 0.25/487

$\epsilon = 2^\circ - 56'$ (DEPLOYED)

IN THE FULLY DEPLOYED GEOMETRY,

ie: $\theta = 0$; AND $\phi = 0$

THEN: $\zeta = 15 - (2^\circ - 56\text{ FT}) = 12^\circ - 4\text{ FT}$

FOR INCREMENTAL ANGLES BETWEEN 0° TO 90°

$\zeta = (12^\circ - 4\text{ FT}) + \theta$

FROM THE TWO SIDES AND INCLUDED ANGLE, THE REMAINING SIDE "g" IS DETERMINED

$$g^2 = \overline{6.5}^{\,2} + f - 2(6.5)f\cos\zeta$$

$$g^2 = \overline{6.5}^{\,2} + \overline{4.88}^{\,2} - 2(6.5)4.88\cos\left[(12^\circ - 4\text{ FT}) + \theta\right]$$

$$g^2 = 66.12 - 63.4\cos\left[\theta + (12^\circ + 4\text{ FT})\right]$$

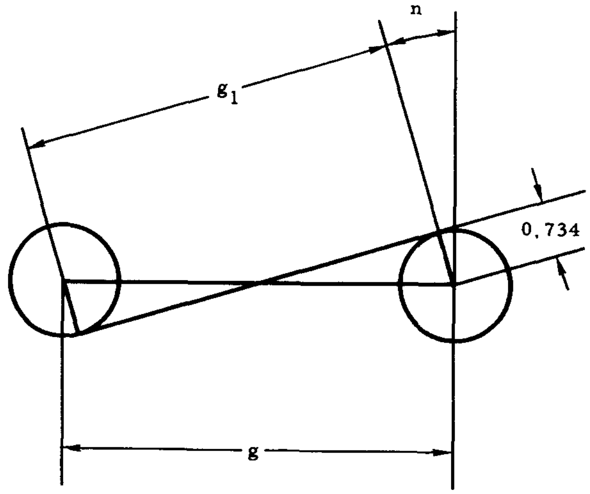
CABLE PITCH DIA = 1.468
R = 0.734

CROSS OVER LENGTH:

$$g_1 = 2\left[\left(\frac{g^2}{2}\right) - \frac{4(0.734)^2}{4}\right]^{1/2}$$

$$g_1 = 2\left[\frac{g^2}{4} - \frac{4(0.539)}{4}\right]^{1/2}$$

$$g_1 = \sqrt{g^2 - 2.157}$$



MODULE KINEMATIC GEOMETRY
TELESCOPING SPOKE MECHANISM - B

ARC LENGTH OF CABLE ON PULLEYS:

CROSS OVER PULLEY ARC LENGTHS

$$\eta = \text{ARC COS } \frac{g_1}{g}$$

TOTAL ARC LENGTH = $2\,\eta\,R$

SPOKE PULLEY ARC LENGTH

$$\psi = \text{ARC SIN } \frac{4.88 \text{ SIN } \zeta}{g}$$

$$\text{ARC LENGTH} = \left(\psi + \frac{15}{180}\right) R$$

OMITTING CONSTANT ANGLE;
ARC LENGTH = ψR

HUB PULLEY ARC LENGTH

$$\omega = \pi - \zeta - \psi$$

TOTAL ARC LENGTH

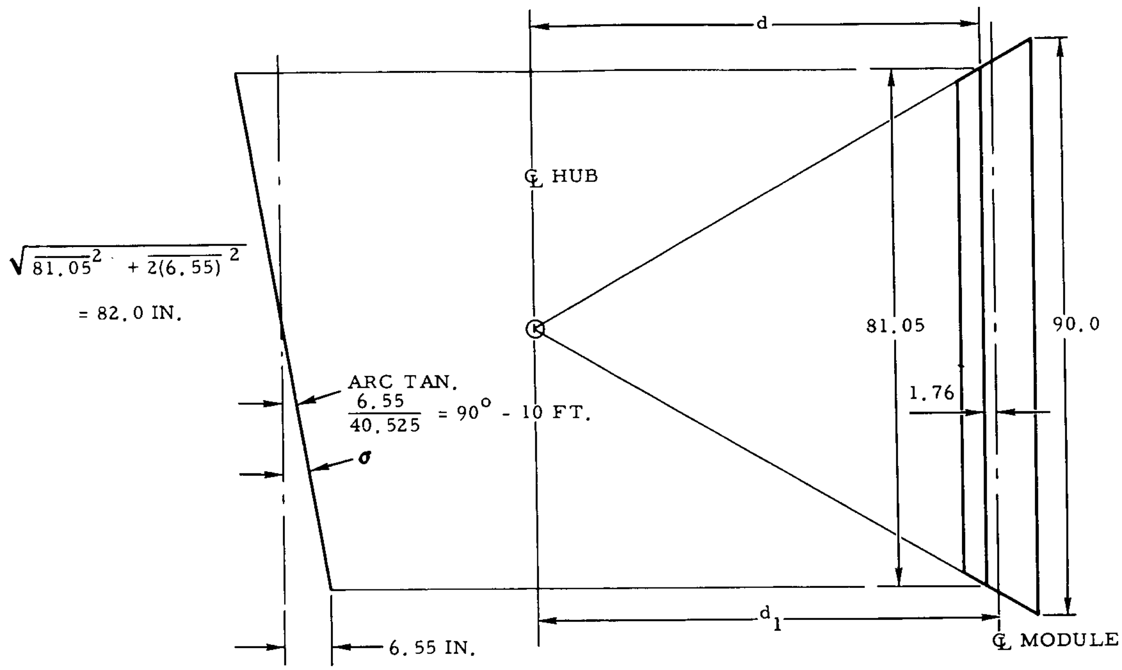
$$= (\pi - \omega)\,R = (\zeta + \psi)\,R$$

THE SUM OF THE CABLE SEGMENTS ARE AS FOLLOWS:

$$\text{LENGTH} = 2g + g_1 + R\,(2\,\eta + \psi + (\zeta + \psi))$$

$$= 2g + g_1 + R\,(2\,\eta + 2\,\psi + \zeta)$$

MODULE KINEMATIC GEOMETRY
TELESCOPING SPOKE-A



$d = \cos 30^\circ (82) \cos(\phi - \tau) = 82 \cos(\phi - (9^\circ - 10')) \cos 30^\circ$

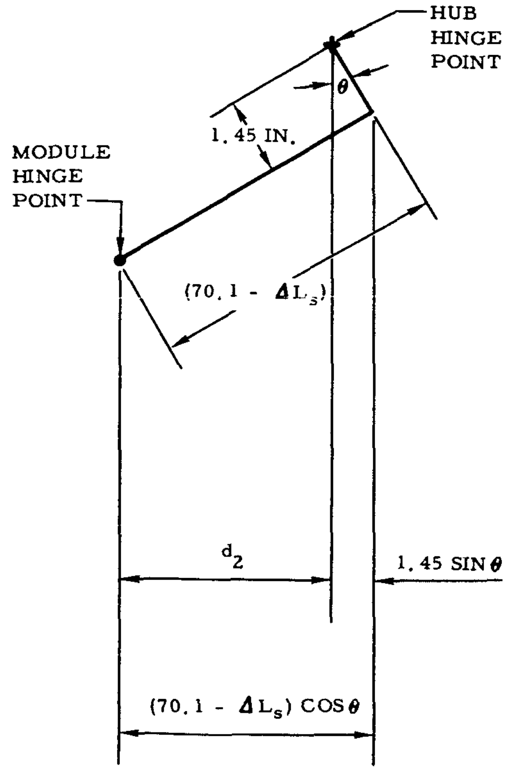
$d = 71 \cos(\phi - \sigma) = 71 \cos(\phi - (90^\circ - 10'))$

IN THE FULLY DEPLOYED COND:

$d = 71 \cos(9^\circ - 10') = 70.1$

MODULE KINEMATIC GEOMETRY
TELESCOPING SPOKE - B

DETERMINATION OF THE CHANGE
IN SPOKE LENGTH "ΔL"



$$(70.1 - \Delta L_s) \cos\theta = d_2 + 1.45 \sin\theta$$

$$70.1 - \Delta L_s = \frac{d_2 + 1.45 \sin\theta}{\cos\theta}$$

$$\Delta L_s = 70.1 - \frac{d_2 + 1.45 \sin\theta}{\cos\theta}$$

$$\Delta L_s = 70.1 - \frac{d - 12.79 + 1.45 \sin\theta}{\cos\theta}$$

$$\Delta L_s = 70.1 - \frac{70.1 \cos\left[(\phi - (9^\circ - 10'))\right] + 1.45 \sin\theta - 12.79}{\cos\theta}$$

THE CABLE TRAVEL AT THE CENTRAL HUB
SPRING LOCATION

$$\Delta L = \Delta L_c - \Delta L_s$$

KINEMATIC GEOMETRY
DISTANCES FROM SPOKE HINGE POINT

$d_1 = d + 1.76$
$d_2 = 25 \cos(11^\circ + \theta)$
$d_3 = 6.188 \cos(-30^\circ + \theta)$
$d_4 = 13 \cos(19^\circ + \theta)$
$d_5 = 6.5 \cos(15^\circ + \theta)$
$h_3 = 6.188 \sin(-30^\circ + \theta)$
$h_4 = 13 \sin(19^\circ + \theta)$
$h_5 = 6.5 \sin(15^\circ + \theta)$

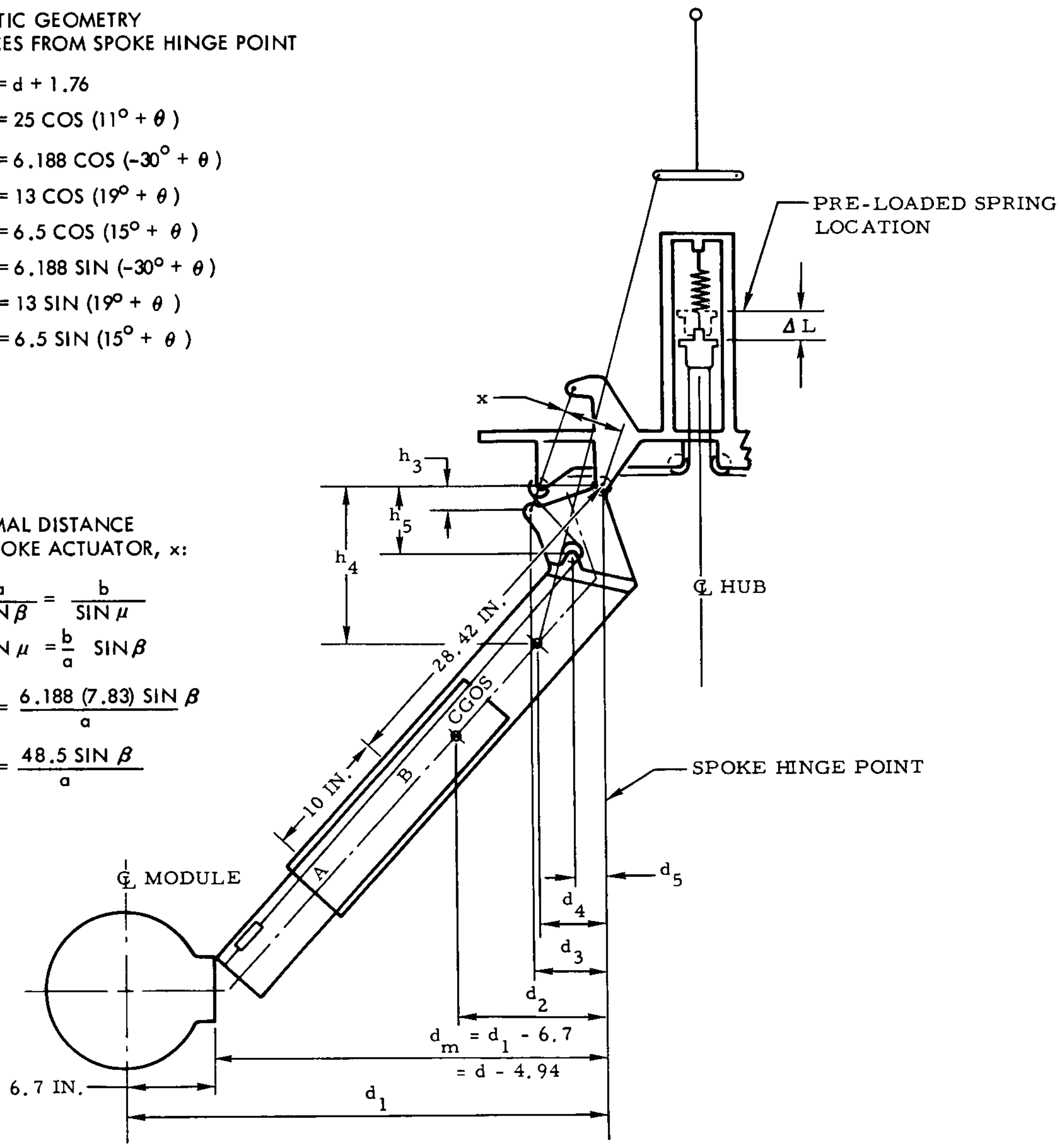
NORMAL DISTANCE
TO SPOKE ACTUATOR, x:

$$\frac{a}{\sin\beta} = \frac{b}{\sin\mu}$$

$$\sin\mu = \frac{b}{a}\sin\beta$$

$$x = \frac{6.188\ (7.83)\ \sin\beta}{a}$$

$$x = \frac{48.5 \sin\beta}{a}$$



INTERACTING LOADS

The spring located in the central hub is designed to assist the modules and inner spoke mechanism in the gravity environment. When the model is in the fully-packaged configuration, the spring should be near its maximum deflection, or extended to the provided limit stop. A diagram of the positions of the loads to be calculated is illustrated in Figure 22.

The spring is installed with a pre-load of 7 pounds.

Spring Constant

$$C = \frac{Ed^4}{8Dn} = \frac{11 \times 10^6\ (.207)^4}{8\ (1.913)^3\ 19} = 19 \text{ pounds/in.}$$

TOTAL WT = 738.13 LB

TOTAL WT PER SPOKE = $\frac{738.13}{3}$ = 269.04 LB

SIGN CONVENTION (+) COUNTERCLOCKWISE

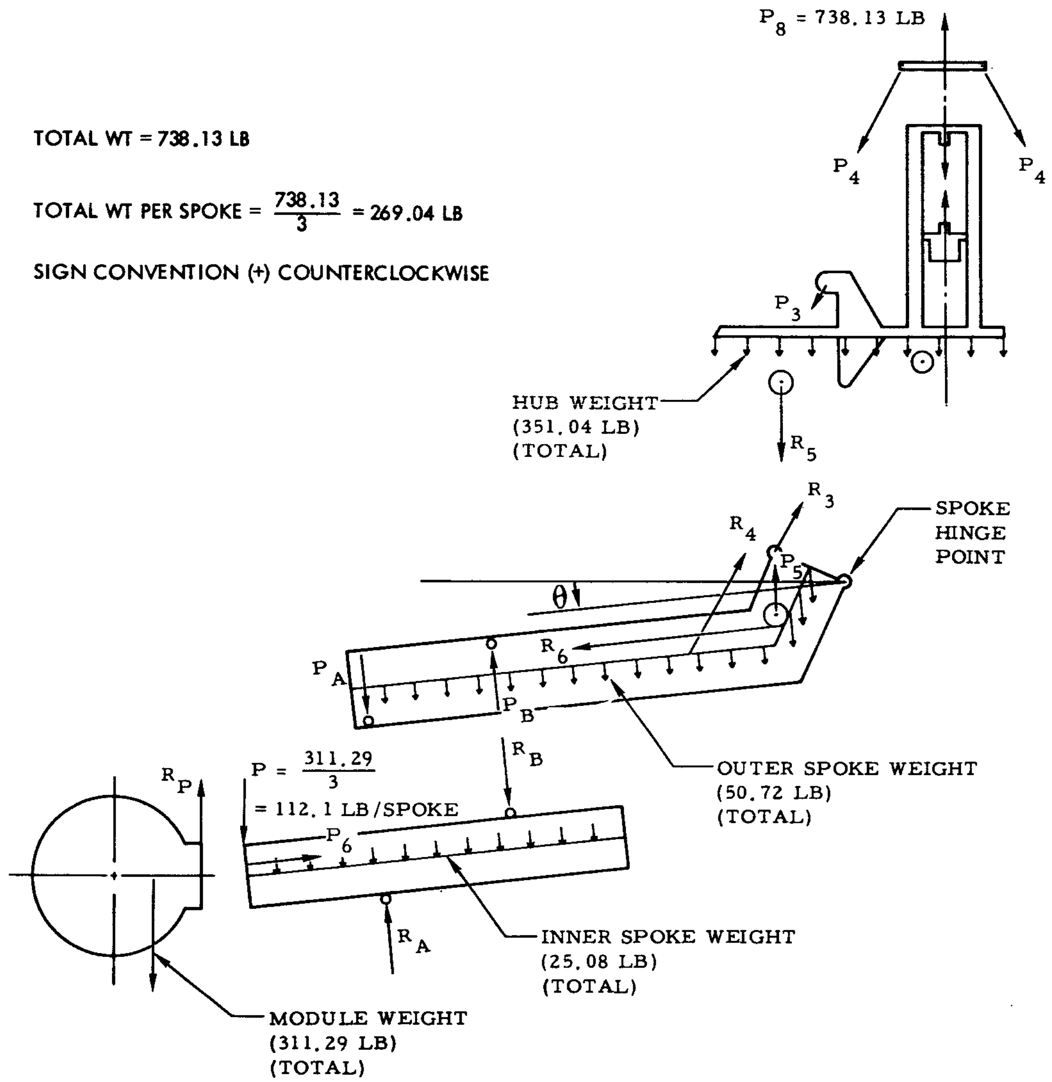


Figure 22. Free Body Diagram of Structural Components

Spring Deflection

Due to 7 pound pre-load

$$\Delta L = \frac{P}{C} = 7/19 = 0.368 \text{ in.}$$

Due to maximum extension

Allowable travel = 8 in.

Total deflection = 8.368 in.

Packaged Station Spring Load

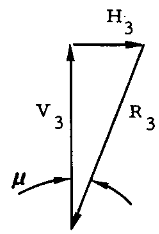
$$P = C\Delta L = 19(8.368) = 159 \text{ pounds}$$

Interacting Loads

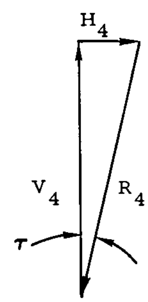
SPOKE ACTUATOR REACTION R_3.

$V_3 = R_3 \cos(\mu + \theta)$

$H_3 = R_3 \sin(\mu + \theta)$



Suspension Cable Reaction R_4



V_4 = SPOKE AND MODULE WT = 269.04 LB

CABLE LENGTH = 34.4 IN.

ANGLE WITH HUB ℄

$$\tau = \text{ARC SIN} \frac{d_4 + 7.85 - 3.0}{34.4}$$

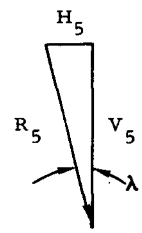
$$\tau = \text{ARC SIN} \frac{d_4 + 4.85}{34.4}$$

$H_4 = V_4 \tan \tau$

$P_4 = V_4 / \cos \tau$

Inner Spoke Cable Reaction R_5

$$R_5 = C(\Delta L + 0.368)$$
$$V_5 = R_5 \cos \lambda$$
$$H_5 = R_5 \sin \lambda$$



WHERE: $\lambda = \omega - \epsilon - 90^\circ = \omega - (92^\circ - 56\ \text{FT})$
AND $\omega = \pi - \zeta - \psi$

Determination of Spoke Hinge Moment, M_s

$$M_s = + P d_m + P_2 d_2 - V_4 d_4 - V_5 d_5 + H_4 h_4 + H_5 h_5$$

$$R_3 = \frac{M_s}{x}$$

Inner and Outer Spoke Reactions

The weight of the inner spoke is assumed to be uniformly distributed and the CG is located in the center or 15.34 inches from each end.

Total weight of inner spokes = 25.08 lb

Weight of each inner spoke = $\frac{25.08}{3}$ = 8.37 lb

Module weight distributed to each spoke

$$P_1 = \frac{311.29}{3} = 103.76 \text{ lb}$$

$$R_A = \frac{\left[(28.42 - \Delta L_s) - 15.345\right] 8.37 \cos \theta}{10} + \frac{\left[(28.42 - \Delta L_s) 103.76\right] \cos \theta}{10}$$

$$R_A = 10.376\,(28.42 - \Delta L_s) \cos \theta \quad 1 + \left(\frac{8.37}{103.76}\right)$$

$$R_A = 10.376\ (28.42-\Delta L_s)\cos\Theta\ (1.081) = 11.2\ (28.42-\Delta L_s)\cos\Theta$$

$$R_B = R_A - (103.76 + 8.37)\cos\Theta$$

$$R_B = R_A - 112.1\cos$$

Module Loads

Length of one module segment:

$$L = \frac{d_m + 6.7 + 7.85}{\cos 30°} = \frac{d_m + 14.55}{.866}$$

Hinge moment:

$$M_m = \frac{\text{Module wt}}{2(6)} \times \frac{L}{2(4)} = \frac{311.29}{12} \times \frac{L}{8}$$

$$M_m = 3.24\ L$$

Module actuator load:

$$x_m = S\ \text{Sin}\ \gamma$$

$$R = \frac{M}{x_m}$$

By using the equations developed in this section, the interacting loads on the structure were calculated. Table 1 summarizes the loads for various values of spoke angle, Θ, from 0° to 90°. Tables 2 through 10 contain the actual calculations of the loads. The calculations shown are based on the condition of no ballast in the model hub.

Table 1. Kinematic Geometry - A

θ (Deg)	B = θ + (51°-31')	Cos 2	96.8 x 3	a^2 = 99.72 - 4	a = $\sqrt{5}$	141.9 - a^2 = 141.9 - 5	Cos δ 7/108.1	δ	ϕ (Deg)
0	51°-31'	.622	60.2	39.52	6.28	102.38	.948	18°-33'	0°-0'
10	61°-31'	.477	46.2	53.52	7.32	88.38	.823	34°-37'	16°-27'
20	71°-31'	.317	30.7	69.02	8.30	72.88	.674	47°-37'	29°-27'
30	81°-31'	.148	14.3	85.42	9.24	56.48	.522	58°-33'	40°-23'
40	91°-31'	-.0265	-2.56	102.28	10.1	39.62	.367	68°-28'	50°-18'
50	101°-31'	-.200	-19.35	119.07	10.9	22.83	.211	77°-49'	59°-39'
60	111°-31'	-.367	-35.5	135.22	11.6	6.68	.0616	86°-28'	68°-18'
70	121°-31'	-.522	-50.5	150.22	12.3	-8.32	-.077	94°-25'	76°-15'
80	131°-31'	-.663	-64.1	163.82	12.8	-21.92	-.2025	101°-41'	83°-31'
90	141°-31'	-.783	-75.8	175.52	13.3	-33.62	-.311	108°-10'	90°-0'

Table 2. Kinematic Geometry - B

1 θ (Deg)	2 $\zeta = (12°\text{-}4') + \theta$	3 $\cos\zeta = \cos$ 2	4 63.4 x 3	5 $g^2 = 66.12 -$ 4	6 $g = \sqrt{5}$	7 $g^2 - 2.157$	8 $g_1 = \sqrt{7}$	9 $\cos\eta =$ 8/6	10 η (radians)	11 Sin ζ	12 4.88/6	13 $\sin\psi =$ 11 x 12	14 ψ (radians)
0	12°-4'	.978	62.0	4.12	2.03	1.96	1.40	.690	.809	.209	2.40	.503	.527
10	22°-4'	.927	58.7	7.42	2.73	5.26	2.29	.839	.575	.376	1.79	.672	.737
20	32°-4'	.847	53.7	12.42	3.53	10.26	3.20	.906	.437	.531	1.38	.734	.824
30	42°-4'	.742	47.1	19.02	4.36	16.86	4.11	.942	.342	.670	1.12	.861	1.037
40	52°-4'	.615	39.0	27.12	5.21	24.96	5.00	.960	.284	.789	.936	.739	.830
50	62°-4'	.468	29.7	36.42	6.04	34.26	5.85	.968	.254	.883	.808	.713	.794
60	72°-4'	.308	19.5	46.62	6.83	44.46	6.67	.977	.215	.951	.714	.679	.746
70	82°-4'	.138	8.75	57.37	7.57	55.21	7.43	.982	.190	.990	.645	.638	.692
80	92°-4'	-.036	-2.28	68.40	8.27	66.24	8.14	.984	.179	.999	.598	.598	.641
90	102°-4'	-.209	-13.25	79.37	8.90	77.21	8.79	.987	.161	.978	.548	.536	.566

Table 3. Kinematic Geometry - C

(1) θ	(2) 2η (Radians)	(3) 2ψ (Radians)	(4) ζ (Radians)	(5) Σ (2), (3) & (4) (Radians)	(6) R x 5 = .734 x (5)	(7) 2g	(8) g_1	(9) Seg. of Cable Length Σ (6), (7) & (8)	(10) ΔL_c = (9) - (9) $\theta = 0$	(11) $\phi - \sigma$ $\phi - (9°-10')$	(12) Cos (11)	(13) d = 71 x (12)
0	1.618	1.054	.211	2.883	2.12	4.06	1.40	7.58	0	-9°-10'	.987	70.1
10	1.150	1.474	.385	3.009	2.20	5.46	2.29	9.95	2.37	7°-17'	.992	70.4
20	.874	1.648	.560	3.082	2.26	7.06	3.20	12.52	3.94	20°-17'	.938	66.5
30	.684	2.074	.734	3.492	2.56	8.72	4.11	15.39	7.81	31°-13'	.855	60.6
40	.568	1.660	.909	3.137	2.30	10.42	5.00	17.72	10.14	41°-8'	.753	53.5
50	.508	1.588	1.083	3.179	2.33	12.08	5.85	20.26	12.68	50°-29'	.636	45.1
60	.430	1.492	1.258	3.180	2.33	13.66	6.67	22.66	15.08	59°-8'	.513	36.4
70	.380	1.384	1.432	3.196	2.34	15.14	7.43	24.91	17.33	67°-5'	.389	27.6
80	.358	1.282	1.607	3.247	2.38	16.54	8.14	27.06	19.48	74°-21'	.270	19.2
90	.322	1.132	1.781	3.235	2.37	17.80	8.79	28.96	21.38	80°-50'	.159	11.3

Table 4. Kinematic Geometry - D

θ	1.45 Sin θ	d	② + ③ -12.79	$\frac{④}{\text{Cos } \theta}$	ΔL_s = 57.31 - ⑤	$\Delta L = \Delta L_c - \Delta L_s$
0	0	70.1	57.31	57.31	0	0
10	.252	70.4	57.86	58.7	-1.39	.98
20	.496	66.5	54.21	57.7	-.39	3.55
30	.725	60.6	48.54	56.0	1.31	6.50
40	.932	53.5	41.64	54.3	3.01	7.13
50	1.11	45.1	33.42	51.9	5.41	7.27
60	1.255	36.4	24.87	49.7	7.61	7.47
70	1.36	27.6	16.17	47.2	10.11	7.22
80	1.43	19.2	7.84	45.1	12.21	7.27
90	1.45	11.3	0	0		*8.00

Note: The spring is limited to 8.00 inches travel

EFFECTS OF BALLAST IN THE CENTRAL HUB

Due to the addition of ballast the vertical reaction component of the suspension cable V_4 will be increased as follows:

$$V_4 = 269.04 + \frac{\text{Ballast wt}}{3}$$

The spoke hinge moment, M_S and spoke reaction R_3 is determined as previously, using various values of V_4.

In designing the model, a cable support was attached to the spoke causing the hub to act as a counterbalance to reduce the load in the spoke actuators. It is evident from an examination of the free body diagram (Figure 22) that an increase of the hub weight would result in a spoke actuator load decrease. The calculations for the reaction loads presented in Tables 1 thru 10 are based on no additional ballast load in the hub. Table 11 summarizes the calculations for determining spoke actuator loads with various amounts of ballast in the hub. The results of these calculations are plotted in Figure 23 as a function of the actuator length. The module actuator load is also presented on this figure for reference. Figure 24 shows the maximum load in the spoke actuators as a function of the amount of ballast that is placed in the hub.

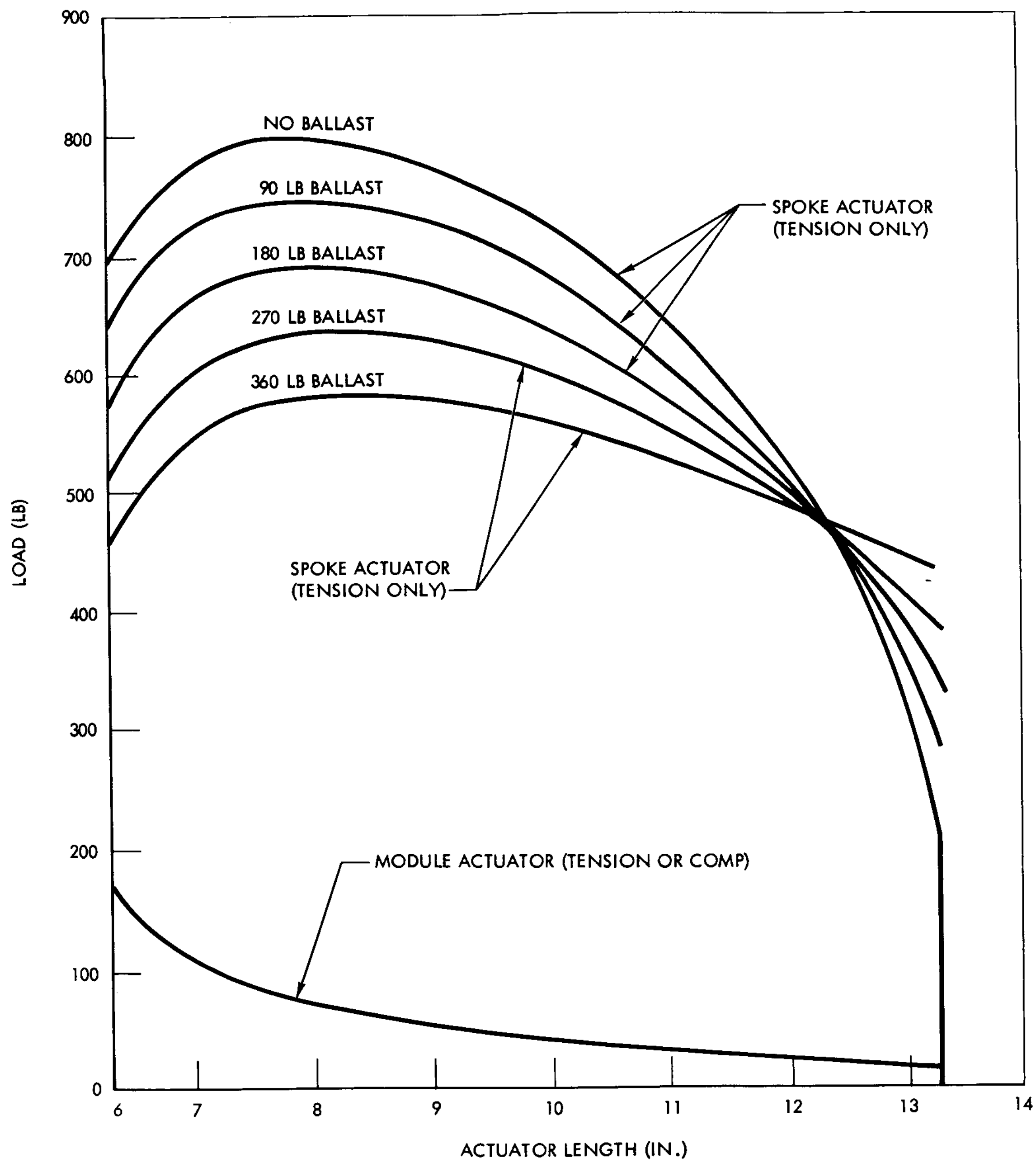


Figure 23. Actuator Load Versus Length (lg)

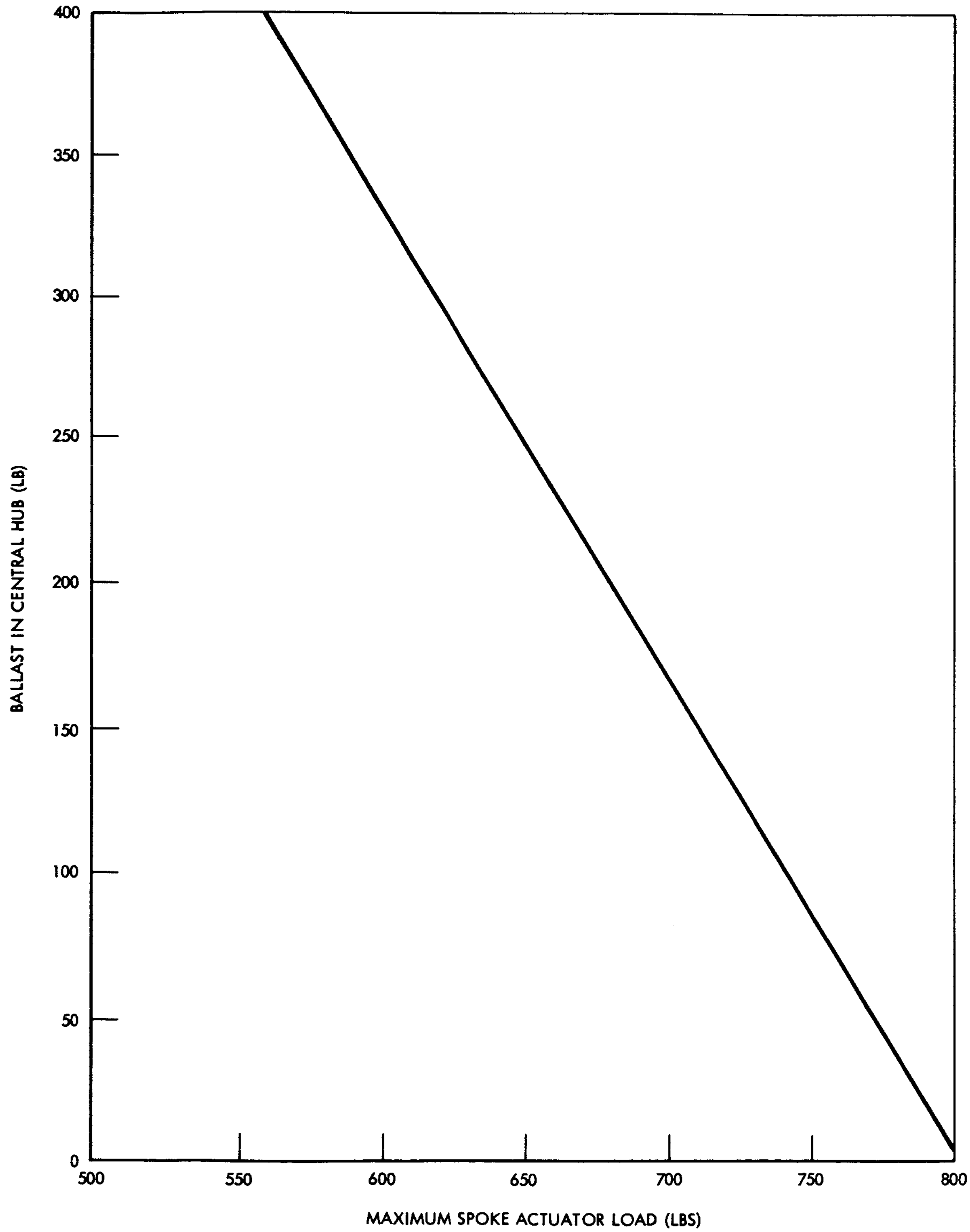


Figure 24. Ballast Versus Maximum Spoke Actuator Load (1g)

Table 5. Kinematic Geometry - E

(1) θ	(2) $d_m = d - 12.79$	(3) $\theta + 11°$	(4) Cos (3)	(5) $d_2 = 25 \times$ (4)	(6) $-30° + \theta$	(7) Cos (6)	(8) $d_3 = 6.188 \times$ (7)	(9) $19° + \theta$	(10) Cos (9)	(11) $d_4 = 13 \times$ (10)	(12) $15° + \theta$	(13) Cos (12)	(14) $d_5 = 6.5 \times$ (13)
0	57.31	11°	.982	24.8	-30°	.866	5.35	19°	.946	12.3	15°	.966	6.28
10	57.61	21°	.934	23.4	-20°	.940	5.81	29°	.875	11.4	25°	.906	5.89
20	53.71	31°	.857	21.4	-10°	.985	6.09	39°	.777	10.1	35°	.819	5.32
30	47.81	41°	.755	18.9	0°	1.00	6.19	49°	.656	8.52	45°	.707	4.60
40	40.71	51°	.629	15.7	10°	.985	6.09	59°	.515	6.70	55°	.574	3.73
50	32.31	61°	.485	12.1	20°	.940	5.81	69°	.358	4.65	65°	.423	2.75
60	23.61	71°	.326	8.15	30°	.866	5.35	79°	.191	2.48	75°	.259	1.685
70	14.81	81°	.156	3.90	40°	.766	4.74	89°	.0175	.228	85°	.0872	.567
80	6.41	91°	-.0175	.437	50°	.643	3.98	99°	-.156	-2.25	95°	-.0872	-.567
90	-1.49	101°	-.191	-4.77	60°	.500	3.09	109°	-.326	-4.24	105°	-.259	-1.685

Table 6. Kinematic Geometry - F

1 θ	2 Sin (-30°-θ) Sin (Col 6 Table 5)	3 h_3 = 6.188 x 2	4 Sin (19°+θ) Sin (Col 9 Table 5)	5 h_4 = 13 x 4	6 Sin (15°+θ) Sin (Col 12 Table 5)	7 h_5 = 6.5 x 6	8 Sin β Sin (Col 2 Table 1)	9 a (Col 6 Table 1)	10 8/9	11 b	12 Sin μ = 10 x 11	14 x = 48.5 x 10
0	-.500	-3.10	.326	4.24	.2588	1.282	.7828	6.28	.1246	7.83	.975	6.05
10	-.342	-2.12	.4848	6.29	.4226	2.75	.8790	7.32	.1200		.940	5.82
20	-.174	-1.08	.6293	8.17	.5736	3.73	.9484	8.30	.1140		.892	5.54
30	0	0	.7547	9.80	.7071	4.60	.9891	9.24	.1070		.837	5.19
40	.174	1.08	.8572	11.14	.8192	5.32	.9996	10.10	.0989		.774	4.80
50	.342	2.12	.9336	12.12	.9063	5.90	.9799	10.90	.0899		.704	4.36
60	.500	3.10	.9816	12.78	.9659	6.28	.9303	11.60	.0802		.628	3.89
70	.643	3.98	.9998	12.99	.9962	6.48	.8525	12.30	.0693		.543	3.36
80	.766	4.75	.9877	12.85	.9962	6.48	.7488	12.80	.0584		.456	2.83
90	.866	5.36	.9455	12.30	.9659	6.29	.6223	13.30	.0468	7.83	.366	2.27

Table 7. Interacting Loads - A

1 θ	2 $P\,d_m = 112.1 \times d_m$	3 $P_2\,d_2 = 18.91 \times d_2$	4 $-V_4 d_4 = -269.04 \times d_4$	5 ΔL	6 $\Delta L + .368$	7 $R_5 = 19 \times$ 6	8 ζ (Rad)	9 ψ (Rad)	10 $\omega = \pi -$ 8 $-$ 9 (Rad)	11 $\lambda =$ 10 $-(92°-56')$ = 10 -1.621 (Rad)	12 $\cos\lambda = \cos$ 11	13 $V_5 =$ 7 $\times$ 12	14 $-V_5 d_5$	15 Σ 2, 3, 4 & 14
0	6420	469	-3310	0	.368	7.0	.211	.527	2.403	.782	.7083	4.96	-31	3548
10	6450	443	-3070	.98	1.348	25.6	.385	.737	2.019	.498	.8784	22.4	-132	3691
20	6020	405	-2720	3.55	3.918	74.5	.560	.824	1.757	.136	.9908	73.9	-393	3312
30	5360	358	-2294	6.50	6.868	103.1	.734	1.037	1.370	-.251	.9686	100	-460	2964
40	4560	297	-1804	7.13	7.498	142.5	.909	.830	1.402	-.219	.976	139	-518	2535
50	3620	229	-1252	7.27	7.638	145	1.083	.794	1.264	-.357	.937	136	-374	2223
60	2650	154	-667	7.47	7.838	149	1.258	.746	1.137	-.485	.877	131	-221	1916
70	1660	74	-61	7.22	7.588	144	1.432	.692	1.017	-.604	.823	119	-67	1606
80	719	8	+605	7.27	7.638	145	1.607	.641	.893	-.728	.748	108	+62	1394
90	-167	-9	+1140	8.00	8.368	159	1.781	.566	.794	-.827	.677	107	+180	1144

Table 8. Interacting Loads - B

(1) θ	(2) $d_4 + 4.85$	(3) $\sin\tau =$ (2)/34.4	(4) τ	(5) $\cos\tau$	(6) $\tan\tau$	(7) $H_4 =$ 269.04 x (6)	(8) $H_4 h_4$	(9) $\sin\lambda$	(10) $H_5 = R_5 \times$ (9)	(11) $H_5 h_5$	(12) $M_s =$ (8) + (11) + (Col (15) Table 7)	(13) x = Col (14) Table 6	(14) $R_3 =$ (12)/(13)
0	17.15	.498	29°-52'	.867	.574	154.5	655	.706	4.94	6.34	4209	6.05	695
10	16.25	.472	28°-10'	.882	.535	144	906	.478	12.3	33.7	4631	5.82	795
20	14.95	.435	25°-47'	.900	.483	130	1062	.136	10.12	37.8	4412	5.54	795
30	13.37	.388	22°-50'	.922	.421	112	1099	-.249	-25.7	-118	3945	5.19	760
40	11.55	.336	19°-38'	.942	.357	96	1070	-.217	-30.9	-164.5	3440	4.80	717
50	9.50	.276	16°-2'	.961	.287	77.2	936	-.350	-50.7	-299	2860	4.36	656
60	7.33	.213	12°-18'	.977	.218	58.6	748	-.480	-71.5	-450	2214	3.89	568
70	5.08	.1477	8°-30'	.989	.149	40.1	520	-.568	-81.2	-530	1596	3.36	475
80	2.60	.0756	4°-20'	.997	.0758	20.4	262	-.664	-96.4	-625	1031	2.83	354
90	.61	.01773	1°-1'	1.000	.01775	4.72	58	-.736	-117	-736	466	2.27	205

Table 9. Interacting Loads - C

1 θ	2 $28.42-\Delta L_s$	3 11.2×2	4 $\cos\theta$	5 $R_A = 3 \times 4$	6 $112.1 \cos\theta$ 112.1×4	7 $R_B = 5 - 6$	8 δ	9 $\sin\delta$	10 $x_m = 5 \sin\delta = 5 \times 9$	11 d_m	12 $d_m + 14.55$	13 $L = 12/.866$	14 $M_m = 3.24 \times 13$	15 $R = 14/10$
0	28.42	318	1.0	318	112	206	18°-33'	.3181	1.59	57.31	71.86	83.0	269	170
10	27.44	307	.9848	302	110	192	34°-37'	.5681	2.84	57.61	72.16	83.4	270	95
20	24.87	278	.9397	262	105	157	47°-37'	.7386	3.69	53.71	68.26	78.9	256	69
30	21.92	246	.8660	213	97	116	58°-33'	.8531	4.27	47.81	62.36	72.0	233	55
40	21.29	239	.7660	183	86	97	68°-28'	.9302	4.66	40.71	55.26	63.8	207	45
50	21.15	237	.6428	153	72	81	77°-49'	.9775	4.89	32.31	46.86	54.1	175	36
60	20.95	235	.5000	117	56	61	86°-28'	.9981	5.00	23.61	38.16	44.0	143	29
70	21.20	238	.3420	81	38	43	94°-25'	.9970	4.99	14.81	29.36	33.9	110	22
80	21.15	237	.1736	41	19	22	101°-41'	.9793	4.90	6.41	20.96	24.2	80	16
90	20.42	229	0	0	0	0	108°-10'	.9502	4.76	-1.49	13.06	15.1	50	11

Table 10. Interacting Loads Summary

One g Static Load							Ultimate Load Condition					
(1) θ	(2) P_A	(3) P_B	(4) P_3	(5) $P_4 = 269.04/\cos \tau$	(6) P_5	(7) $P_6 =$ (6)/3	(9) P_A 2.6 x (2)	(10) P_B 2.6 x (3)	(11) P_3 2.6 x (4)	(12) P_4 2.6 x (5)	(13) P_5 2.6 x (6)	(14) P_6 2.6 x (7)
0	318	206	695	380	7.0	2.3	825	535	1810	990	18	6
10	302	192	795	306	25.6	8.5	785	500	2070	795	66.5	22
20	262	157	795	272	74.5	25	681	408	2070	705	194	65
30	213	116	760	278	103.1	34	554	302	1980	720	268	88
40	183	97	717	276	142.5	48	476	252	1870	720	370	125
50	153	81	656	287	145.0	48	398	210	1710	745	378	125
60	117	61	568	307	149.0	50	304	159	1480	799	388	130
70	81	43	475	327	144.0	48	210	112	1240	850	374	125
80	41	22	354	360	145.0	48	107	57	920	935	377	125
90	0	0	205	398	159.0	53	0	0	533	1035	414	138

Table 11. Ballast Effects

	90 lb Ballast			180 lb Ballast			270 lb Ballast			360 lb Ballast				
(1) θ	(2) $-V_4d_4 = -299.04 \times d_4$	(3) M_s	(4) R_3	(5) $-V_4d_4 = -329.04 \times d_4$	(6) M_s	(7) R_3	(8) $-V_4d_4 = -359.04 \times d_4$	(9) M_s	(10) R_3	(11) $V_4d_4 = -389.04 \times d_4$	(12) M_s	(13) R_3	(14) d_4	(15) $M_s - V_4d_4$
0	-3680	3839	635	-4050	3469	573	-4410	3109	514	-4790	2729	451	12.3	7519
10	-3410	4291	738	-3750	3951	679	-4090	3611	620	-4430	3271	562	11.4	7701
20	-3020	4112	741	-3330	3802	686	-3620	3512	634	-3930	3202	577	10.1	7132
30	-2550	3689	710	-2810	3429	660	-3060	3179	611	-3320	2919	561	8.52	6239
40	-2000	3244	676	-2210	3034	632	-2400	2844	593	-2610	2634	549	6.70	5244
50	-1390	2724	626	-1530	2582	593	-1670	2442	560	-1810	2302	528	4.65	4112
60	-741	2140	550	-816	2065	531	-890	1991	512	-965	1916	493	2.48	2881
70	-68	1589	474	-75	1582	471	-82	1575	469	-89	1568	466	.228	1657
80	+674	1100	389	+740	1166	410	+808	1234	436	+876	1302	460	-2.25	426
90	+1270	596	262	+1400	726	320	+1530	856	377	+1650	976	430	-4.24	-674

FABRICATION OF MODEL

It became evident that if the design, strength analysis, fabrication and testing of a 1/10-size model of the space station were to be accomplished between mid June and mid October, close coordination of all aspects of the operation would be necessary. A unit within North American Aviation--The General Office Orientation Group--which had extensive experience in the production of display models with ready access to subcontractors for non-flyable hardware, was selected as fabricator. Drawing release, parts rejection and salvage were reduced to a single relationship between the engineering and manufacturing elements.

The tools of manufacture for the model were held to an austere limit, with heavy emphasis on bench layout of the actual parts. Some of the various component parts and their method of fabrication are shown in Figures 25 through 32.

Final assembly of the model was accomplished on wooden cradles resting on the flat factory floor in the deployed position. Freedom from constraint as assembled was accomplished by hand fold-up of the rim modules and spokes, while secured to the hub prior to installation of the actuation system. Internal wire harnesses to the actuators and their limit switches, were spread on the floor, and installed concurrently with the final assembly.

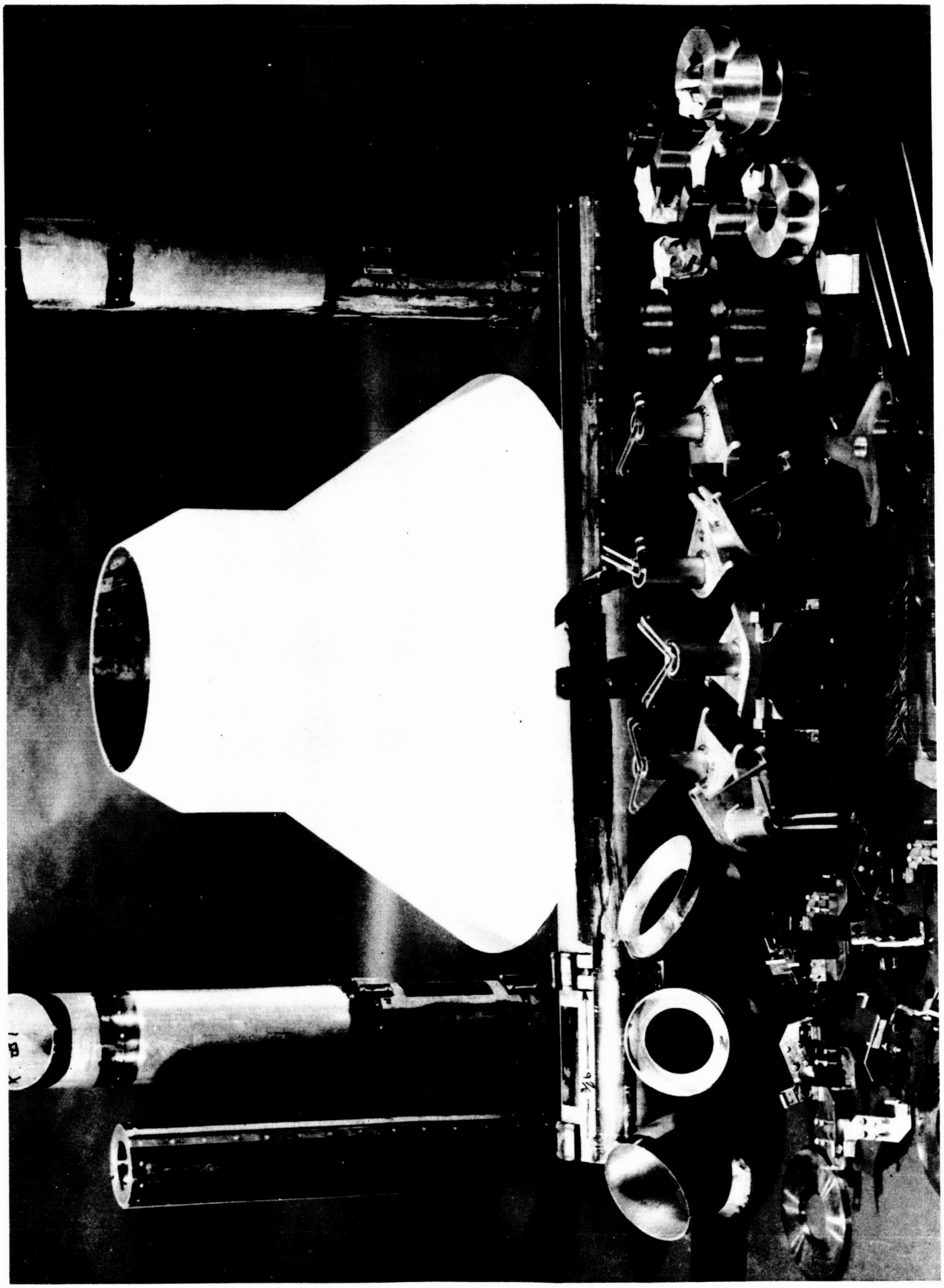


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Figure 25. Detail Parts

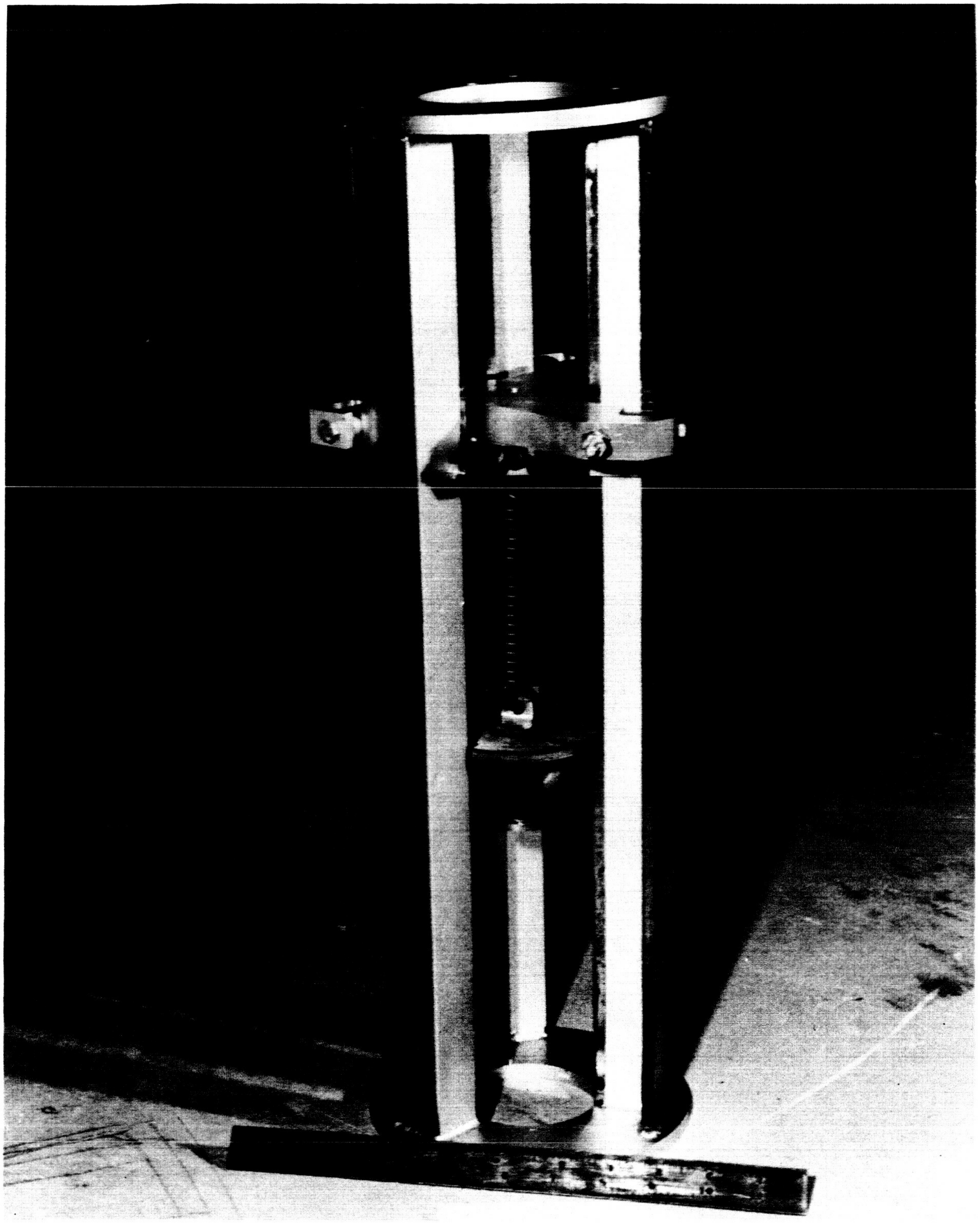

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Figure 26. Cage Assembly Showing Spring

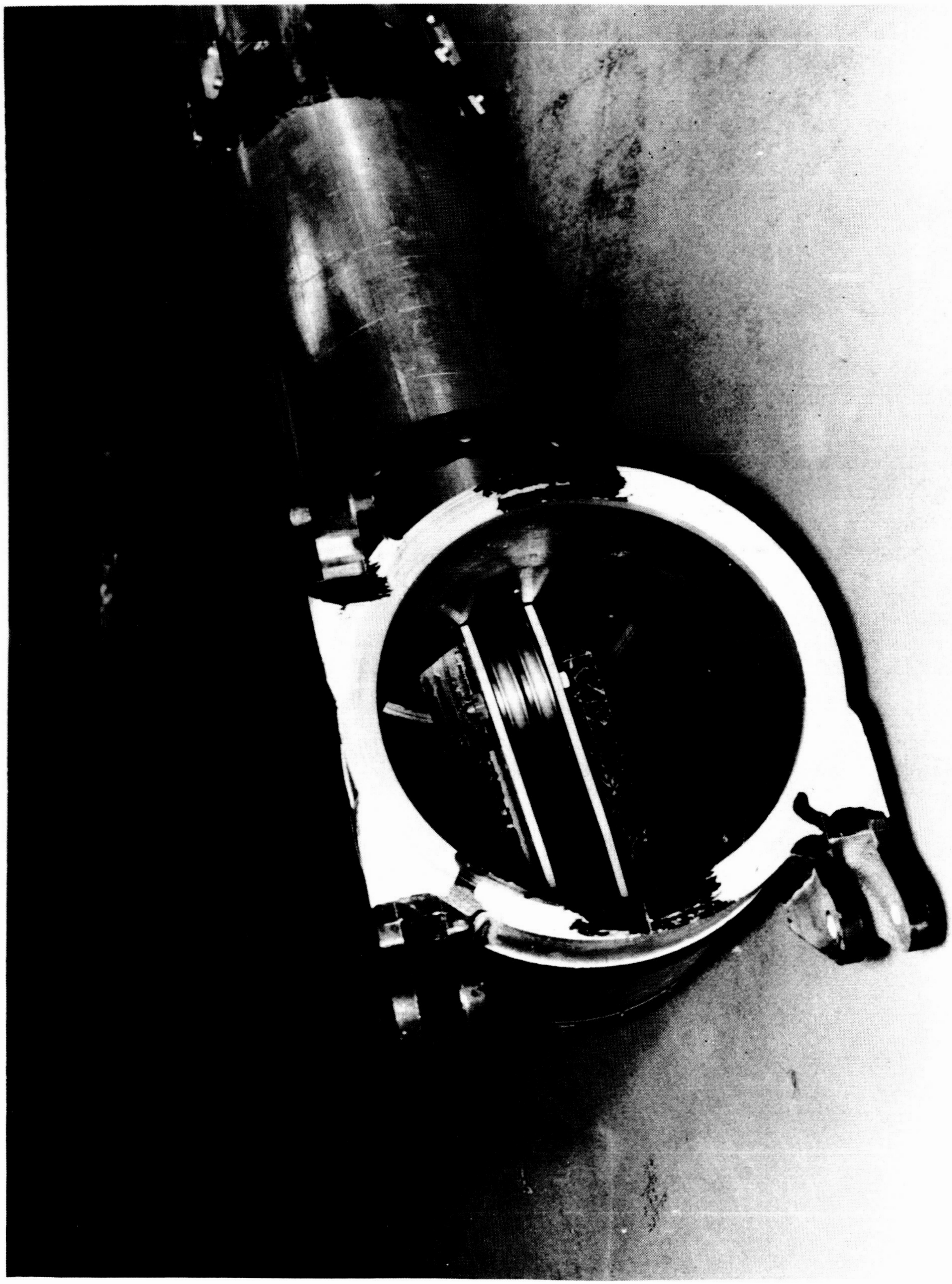

Figure 27. Inboard End of Spoke Showing Details of Extension Control Cable Pivot Pulleys

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Figure 28. Bench Layout on Inboard End of Spoke

700-98-161

700-98-162

Figure 29. Hub Base Weld Assembly

Figure 30. Spoke Assembly

700-98-163

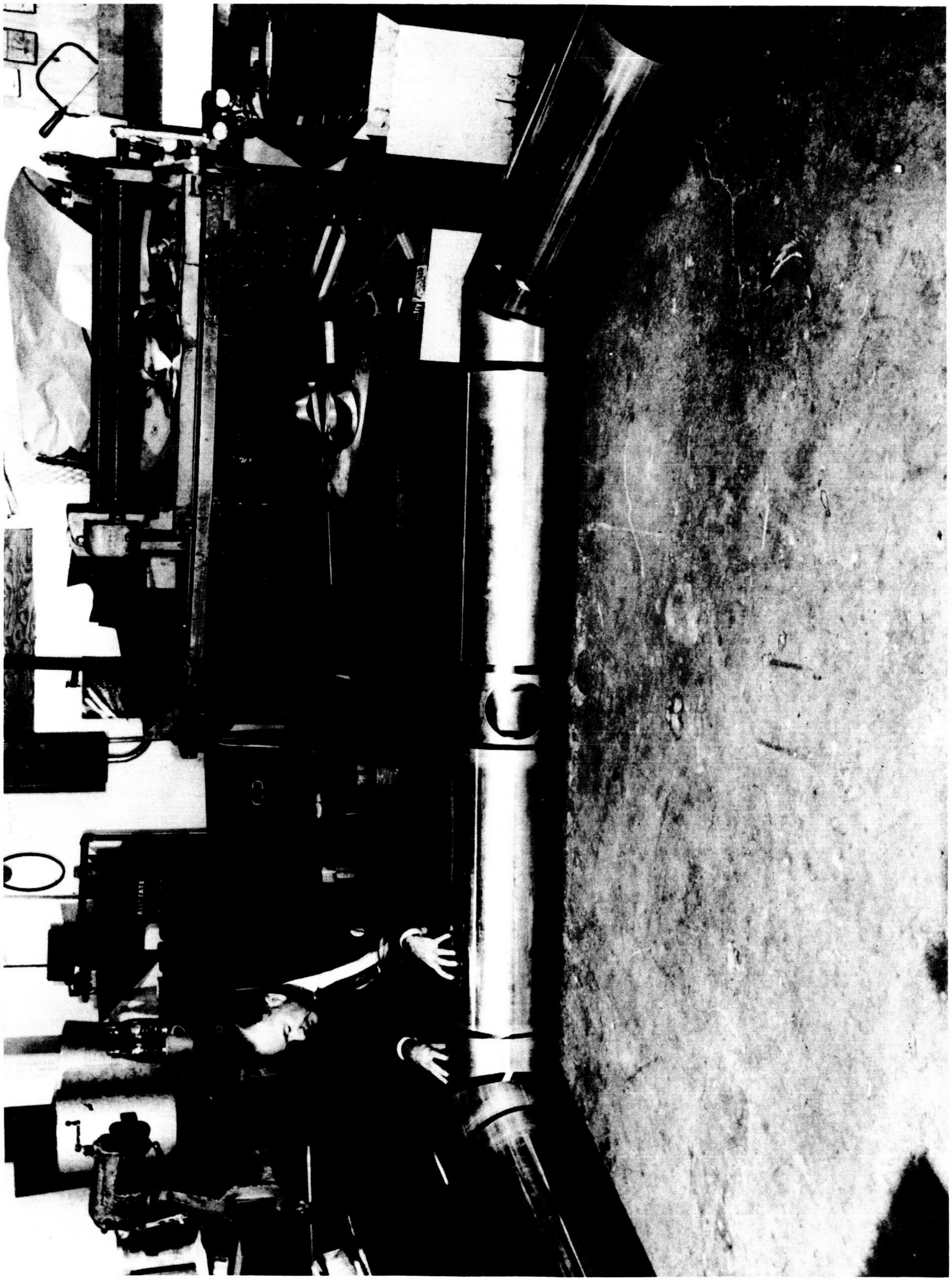

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Figure 31. Rim Module Skin Details

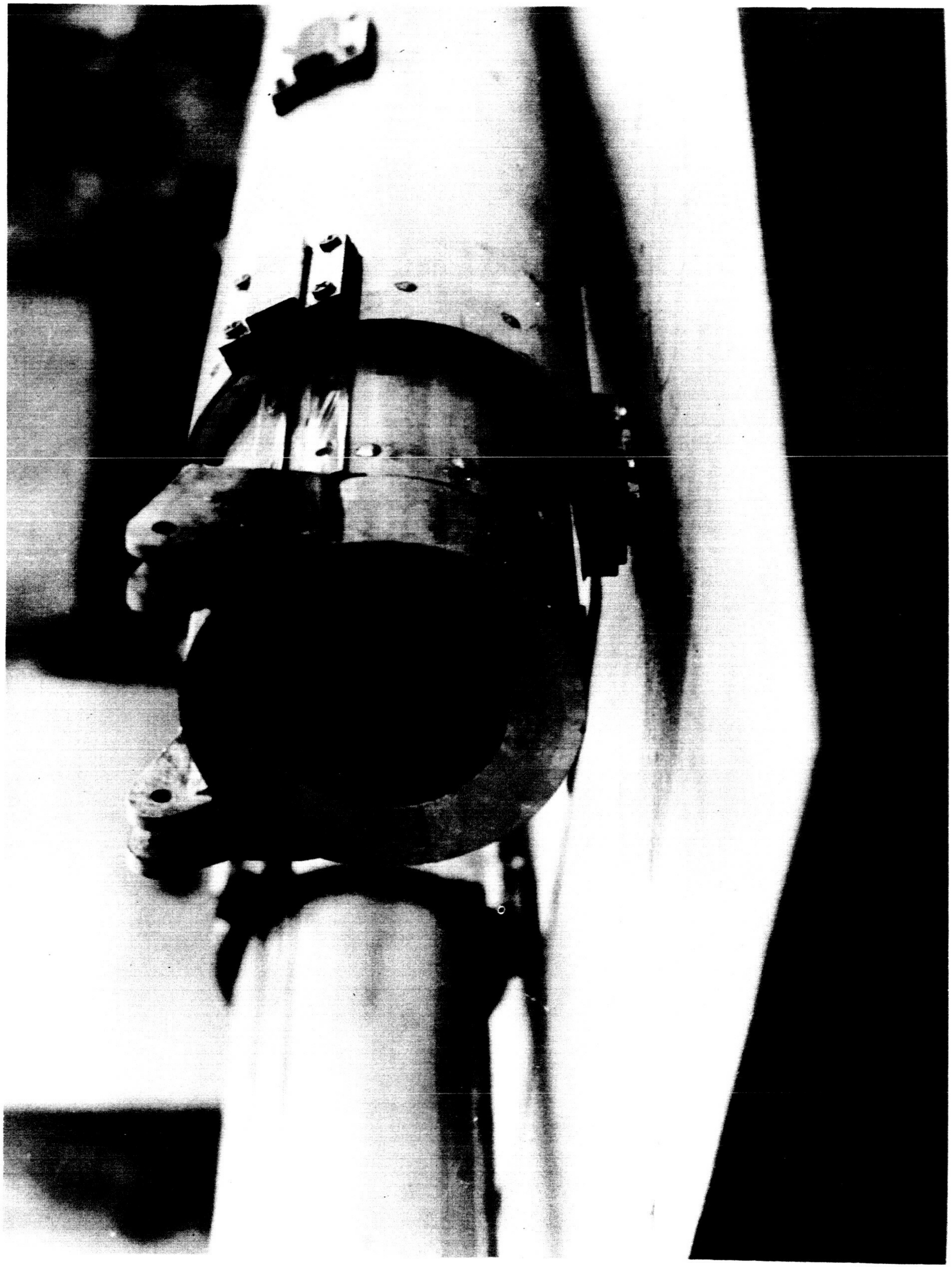


Figure 32. Module End of Spoke Showing Location of Spoke Extension Control Cable Stud

700-98-165

RIGGING OF MODEL FOR OPERATION

Preparation of the tenth-size model of the space station for powered operation is dependent on an accurate adjustment of all limit switches, which stop joint motion at both the stowed and deployed configuration, and also on installation of the deployment actuators at a common length at all locations.

Since all actuators in the system have the same travel, direction, and time element; and the nominal travel of actuation is seven inches, with an allowed quarter inch of overtravel in either extension or retraction; it is apparent that the elements of the model are held symmetrical by the similar lengths at which the actuators are installed; and the limit switches, which stop motion, control the final static relationship of the folded, or deployed, parts of the model.

A precise length of all actuators as assembled would be relatively impossible because of natural accumulation of tolerances in the spoke and module attachments. Similarly, the need for such exactness would likely be avoided, even in a final product for space. In the case of the model, spoke actuators were installed at their true length with the system unconstrained, after which the modules were spaced 1.10 inches apart with blocks, and held in position with tension straps, while their actuators were installed closely within the design extended length of 13 1/4 inches. A rim module actuator was not considered improperly installed at 13 1/4 (plus or minus 3/32 inches). With all actuators installed, the limit switches, which control final stowed position, were then set to signal, "stowing power OFF and braking power ON", approximately 1/64 inch prior to the block position.

With the electrical system checked out, the actuator lengths properly installed, and the stowed position limit switches adjusted, the system was driven to a deployed position and stopped by hand switch so the deployed position limit switches could then be adjusted to signal "deployed power OFF and braking power ON", approximately 1/64 inch prior to the final deployed position.

An explanation for adjusting limit switches to a 1/64 inch-preload is that the rate of rotation of all switch striker-plates is approximately 1/32 inch per second, and full actuator motor-braking to a full stop occurs in about one second. Therefore, the average striker plate motion, once power is switched from drive to braking, is approximately half the rate per second or 1/64 inch.

A significant point in full stop control by limit switches alone is the permanent relationship between the lengths of the actuators and the position of the switches, with the only variable existing in the model. This prevents an accumulation of error which could otherwise lead to unsymmetrical positions of the moving parts.

Spokes in the model must coordinate with the rim modules in angular travel and extension. This function is controlled by a cable system identically situated in each spoke, and it is adjustable to a properly rigged position by means of a threaded stud located in the inboard end of the spoke to module hinge interface (Figure 32).

The threaded stud is not accessible for adjustment to the rig dimension shown in Drawing 7103-56, if the model is assembled because the module covers the location at the outer spoke joint when deployed. The only satisfactory means of adjusting the cable lengths to the rig measurement after deployment of the assembled unit is to lower the deployed model to ground supports and disconnect the rim modules from the three spokes which will then permit exposure of the adjusting studs.

TESTING OF MODEL

Structural testing of the model during construction was not considered necessary because conservative strength margins were imposed during design. Furthermore, it appeared that a model-joint rate of motion of 3/4 degrees per second would allow ample time to stop the model by means of a hand override switch should an actuator fail to coordinate with the system and begin to impose bending loads on the model. Visual inspection would reveal such a failure.

Cable assemblies, all of which support dead weight of all or parts of the model, were proof loaded to 60 percent of the rated breaking strength of the cable according to the design standards of S&ID and MIL-C-5688(FA6-1).

Actuator specification requirements were established by S&ID. These requirements included 1000 pound maximum axial force with a maximum variable between units of 2 percent in time or travel. A life cycle of 200 complete operational excursions was imposed on the actuator design. A five-minute interval was allowed for motor cooling between each direction of stroke.

The supplier selected to design and manufacture the model actuators constructed a load cell suspended in a frame to qualify the units. The test fixture (Figure 33) consists of a hydraulic strut that imposes a load directly on the free end of the operating specimen actuator as hydraulic pressure is unloaded from the strut by means of a hand valve. Axial alignment of the loaded column about the pin joint between the hydraulic strut and the actuator being tested is maintained by a carriage that guides the strut along fixed tubular tracks.

Actuator qualification commenced concurrently with the final assembly of the model. Early tests of the actuators against the load cell made it apparent that the units would operate at the required 1000-pound axial load, but that the motors would become desynchronized at about 450 pound force, or half of the requirement.

The behavior of the motors above 450 pound axial force was shown by testing to be similar to the behavior of induction motors in that a gradual increase in force produced a gradual decrease in speed. No recordings of speed reduction were taken because the deployment system could not operate with any of the several actuators unlocked from the power cycle.

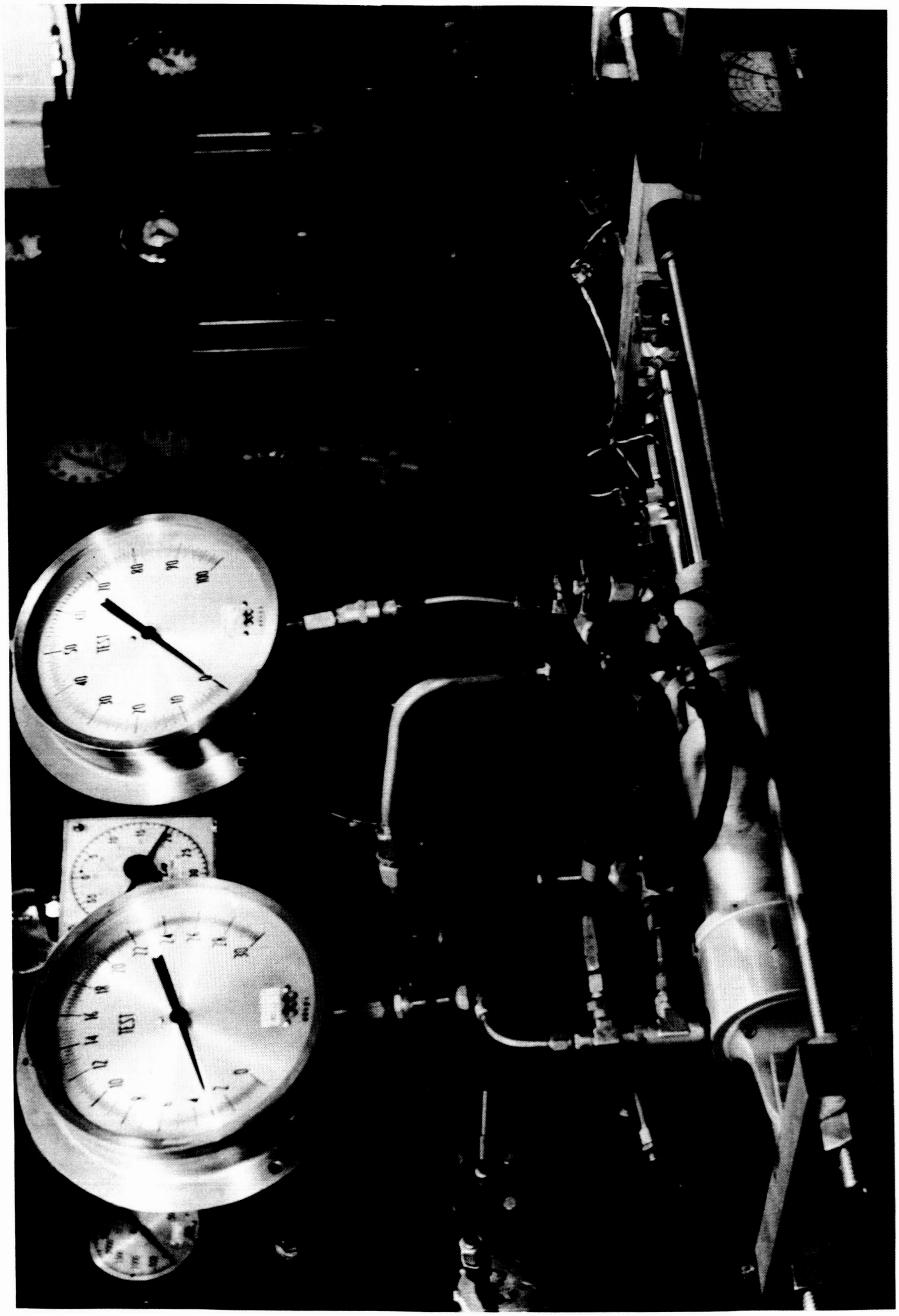


Figure 33. Actuator Test Fixture

The actuators were conditionally accepted from the supplier by S&ID in spite of their inability to qualify to the specification because it was assumed that they would operate sufficiently well to meet scheduled model demonstration commitments.

The model delivered to LRC included actuators that have been rejected by S&ID and are subject to rework when the method of improvement is established.

The supplier is conducting a test program on a single unit. This unit is being redesigned and reworked to improve drive efficiency to meet the specification.

Table 12 is a log of the operation of the model with notations on malfunctions.

Table 12. Model Operation

Date	Time	Remarks
9-20	10:00 AM	Deployed satisfactorily; broke one spoke actuator during foldup; structural interference with body end of actuator; folded satisfactorily after correction
	3:00 PM	Deployed and folded satisfactorily
9-21	3:15 PM	Deployed satisfactorily; broke spoke actuator during foldup; structural interference with larger screw on jack end of actuator; folded satisfactorily after correction
9-24	11:00 AM	Deployed and folded satisfactorily
9-25	9:30 AM	Deployed and folded satisfactorily
9-26	6:00 PM	Deployed and folded satisfactorily
9-27	2:45 PM	Deployed and folded satisfactorily
	3:10 PM	Deployed and folded satisfactorily
9-28	9:30 AM	Deployed and folded satisfactorily
	4:30 PM	Deployed and folded satisfactorily

Table 12. Model Operation (Cont)

Date	Time	Remarks
10-1	11:00 AM	Deployed and folded satisfactorily
	2:00 PM	Deployed and folded satisfactorily
	5:00 PM	Faulty relay prevented deployment; no motion; relay was replaced
10-2	1:00 PM	Deployed 10 degrees before it became evident that actuator at location M9 did not function; inspection revealed that motor was in operation but final gear in train had slipped to disengagement; actuator was replaced
	5:00 PM	Deployed and folded satisfactorily
10-3	11:15 AM	Deployed and folded satisfactorily
10-12	9:30 AM	Deployed and folded satisfactorily
	11:30 AM	Deployed and folded satisfactorily

MODEL OPERATING PROCEDURE

In accordance with the design of the model control system, the following sequence is presented to guide operating personnel:

1. Turn on the power switch. The meter should read between 23 and 27 vdc and both indicator lamps adjacent to the meter should be lit.

2. Place the control switch in the retract position until the model is completely retracted.

3. At this point, the model may be deployed by placing the control switch in the deploy position.

The following points must be observed when operating the model:

1. Allow at least 5 minutes for motor cooling between each cycle of the model.

2. Keep a hand on the control switch continuously during deployment or retraction of the model.

3. Turning off either the control switch or the power switch will stop the model drive.

4. Always return the control switch to STOP after reaching a limit, and do not toggle the control switch indiscriminately.

5. The model must be fully retracted before it can be deployed.

PROPOSED TEST PLAN

Because the completed model of the space station was shipped to Langley Research Center several days earlier than was originally intended, S&ID was not able to perform many measurements or experiments. There are a number of experiments that should be performed with the model because they could contribute valuable data upon which to base the design of the full-scale SDSS. Several experiments of interest are listed in this section. The listing is not intended to be complete, and it does not define relative importance or a preferred sequence of the experiments.

NUMBER OF ACTUATORS REQUIRED FOR DEPLOYMENT

In designing the model, two actuators were placed at each module joint. It is believed that the deployment would still proceed satisfactorily if the actuators were removed from alternate joints. In performing this experiment, the three pairs of actuators should be completely removed from the model. Care should be taken that binding does not occur in any of the joints. This should be checked by means of visual inspection of each of the joints during the deployment sequence.

This experiment might be varied by removing one actuator from each joint to determine if satisfactory deployment could be accomplished in this matter. It is suggested, however, that this variation of the experiment be attempted only after considerable experience with model operation has been attained.

ACTUATOR LOADS

An analytical determination of the loads that would be encountered in the spoke and module actuators was made during the course of the design of the 1/10-scale model. It was not determined whether the actuator loads would be greater or less than the calculated loads. The experiment to determine this would consist of placing strain gauges at appropriate locations on the actuator attachment brackets. The gauges should be placed in a location that would permit readings to be obtained throughout the deployment cycle; i.e., they cannot be placed on the moving screws of the actuators or in any similar location. Readings should be taken throughout the deployment cycle. It would also be desirable to measure the loads on the actuators during the course of the experiments described in the preceding paragraph.

SYNCHRONIZATION OF ACTUATORS

The actuators that were installed in the space station model were designed to operate at a speed that would not vary by more than 2 percent among all the actuators. It is realized that the slight difference in rate of operation may require that the actuator lengths be adjusted after a certain number of deployment cycles. This assumption has not been confirmed, however. It would be desirable to precisely measure the lengths of each actuator at the beginning and at the end of the deployment cycle for each operation. If a log of these measurements were kept, it would provide an indication of when and if any actuator might need some adjustment. It is possible that this particular installation of microswitches may prevent any significant build-up of error in actuator position over a period of time. The advisability of keeping this log is obvious, for the actuator may overrun its extreme positions before contact is made with the microswitch.

SYNCHRONIZATION OF SPOKE LENGTHS

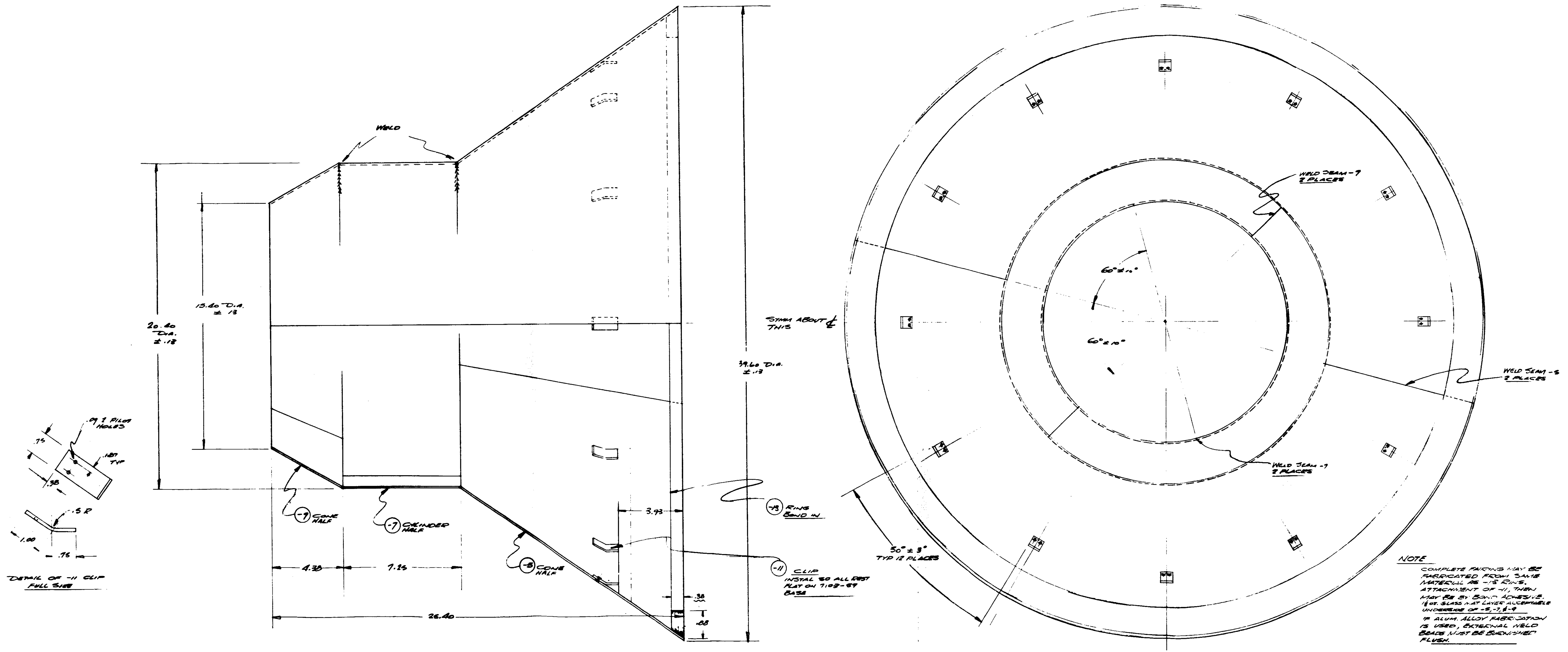
It is believed that it will be necessary to provide a positive control mechanism on the telescoping spokes of the space station. The kinematic analysis has indicated that it is unlikely that deployment could occur satisfactorily without control of spoke lengths. It would be desirable to determine the degree of asymmetry that can be tolerated with respect to spoke lengths before binding would occur in the joints.

This experiment could be carried out rather simply by lengthening the cable in one spoke by relatively small amounts, deploying the model, and measuring the loads in each of the actuators. The cable could be gradually lengthened until excessive binding would begin to occur in the joints.

An extreme test would involve the complete elimination of the spoke synchronization mechanism. This test would have to be performed very carefully, because it could easily result in structural damage to the model.

SYNCHRONIZATION OF MODULE ACTUATORS

While it is obviously desirable to maintain complete symmetry of deployment in the SDSS, it is recognized that there may be occasions when symmetry would not be maintained, particularly if actuators should be mismatched. To determine the degree of asymmetry that could be tolerated, one or more module actuators can be made to operate at a lower rate than the others. Alternatively, the initiation of the operation of one or more actuators can be delayed for a prespecified period of time. The extent of the loss in synchronization among the actuators can be varied to determine what limits may exist. As in previous experiments, it would be desirable to measure the loads on the actuators during all deployment cycles.

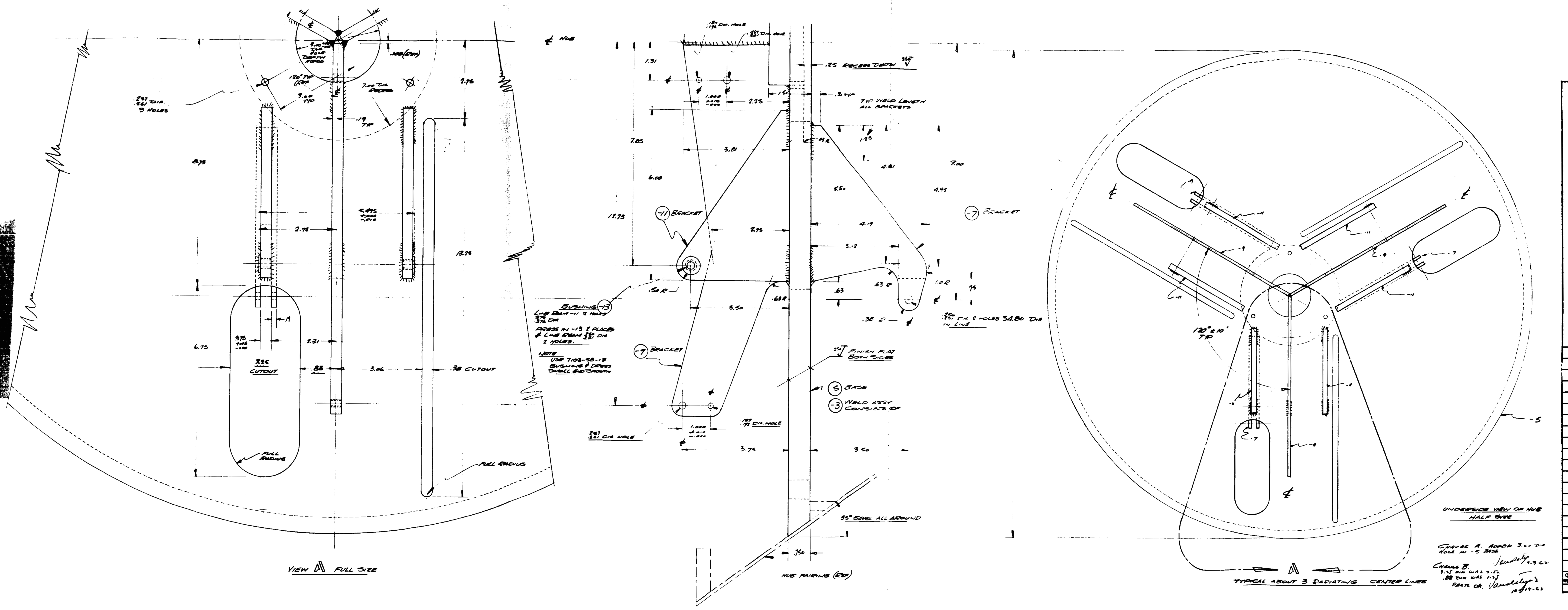


SYM	REVISIONS DESCRIPTION	DATE	APPROVED
	1. MAY BE REWORKED 3. RECORD CHANGE 2. CANNOT BE REWORKED 4. NOW SHOP PRACTICE 5. PARTS MADE OK		

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA: SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
											020
											019
											018
											017
											016
											015
											014
											013
											012
											011
											010
											009
					1	-13	RING		GLASS CLOTH & POLYESTER RESIN LAYUP	#311/60-39 GLASS CLOTH SELECTRON RESIN #5834	008
											007
					12	-11	CLIP	--	6061-T6 ALUM ALLOY SHEET (COMML)	.13 x .88 x 1.88	006
					2	-9	CONE			.13 x 10 x 40	005
					2	-7	CYLINDER			.13 x 8 x 33	004
					2	-5	CONE			.13 x 68 x 74	003
					1	-3	WELD ASSY		CONSISTS OF -5-7 & -9		002
					1	-1	BOND ASSY		CONSISTS OF -3 & -13		001

LIST OF MATERIAL OR PARTS LIST

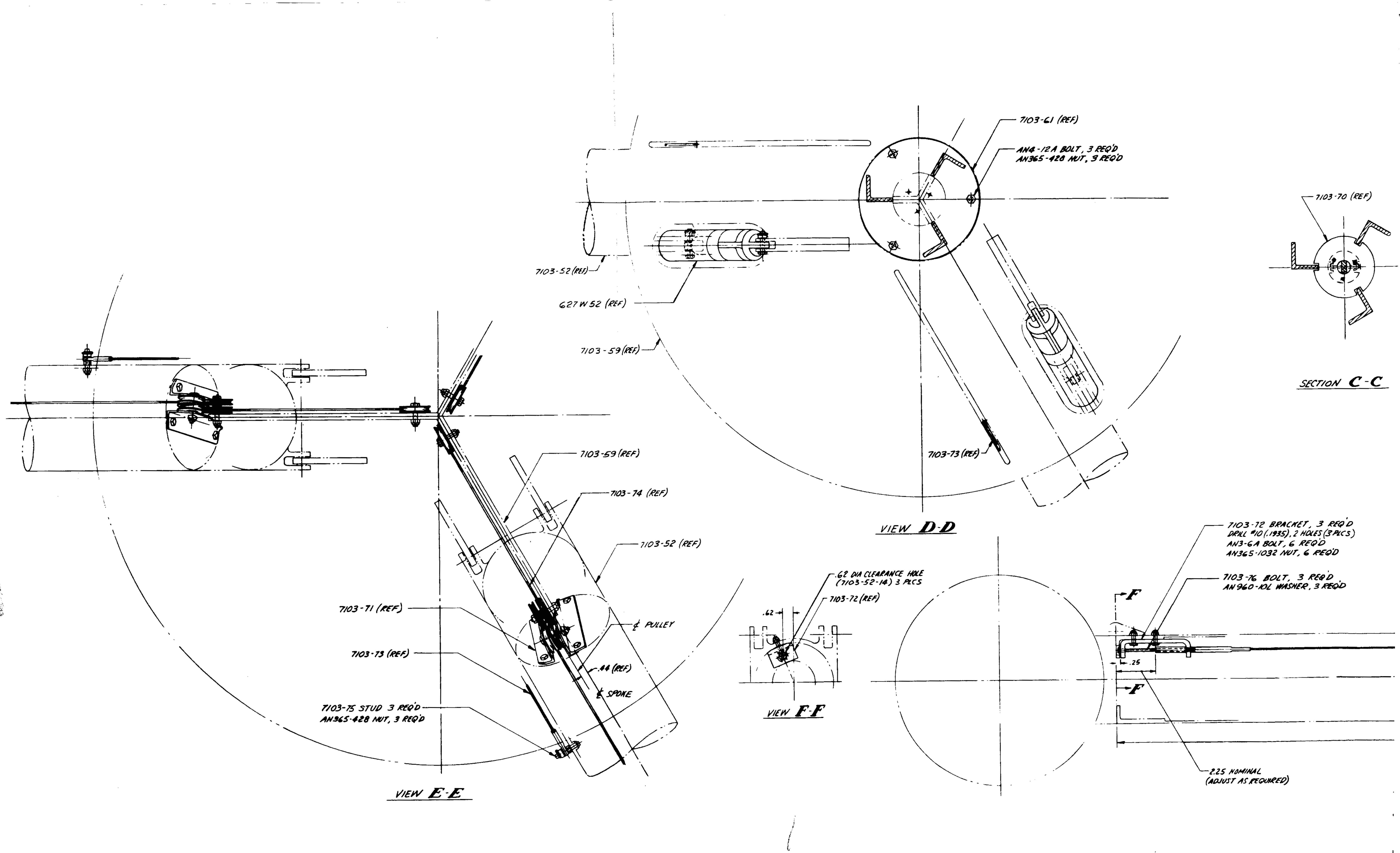
Drawing 7103-60 External Fairing - Hub



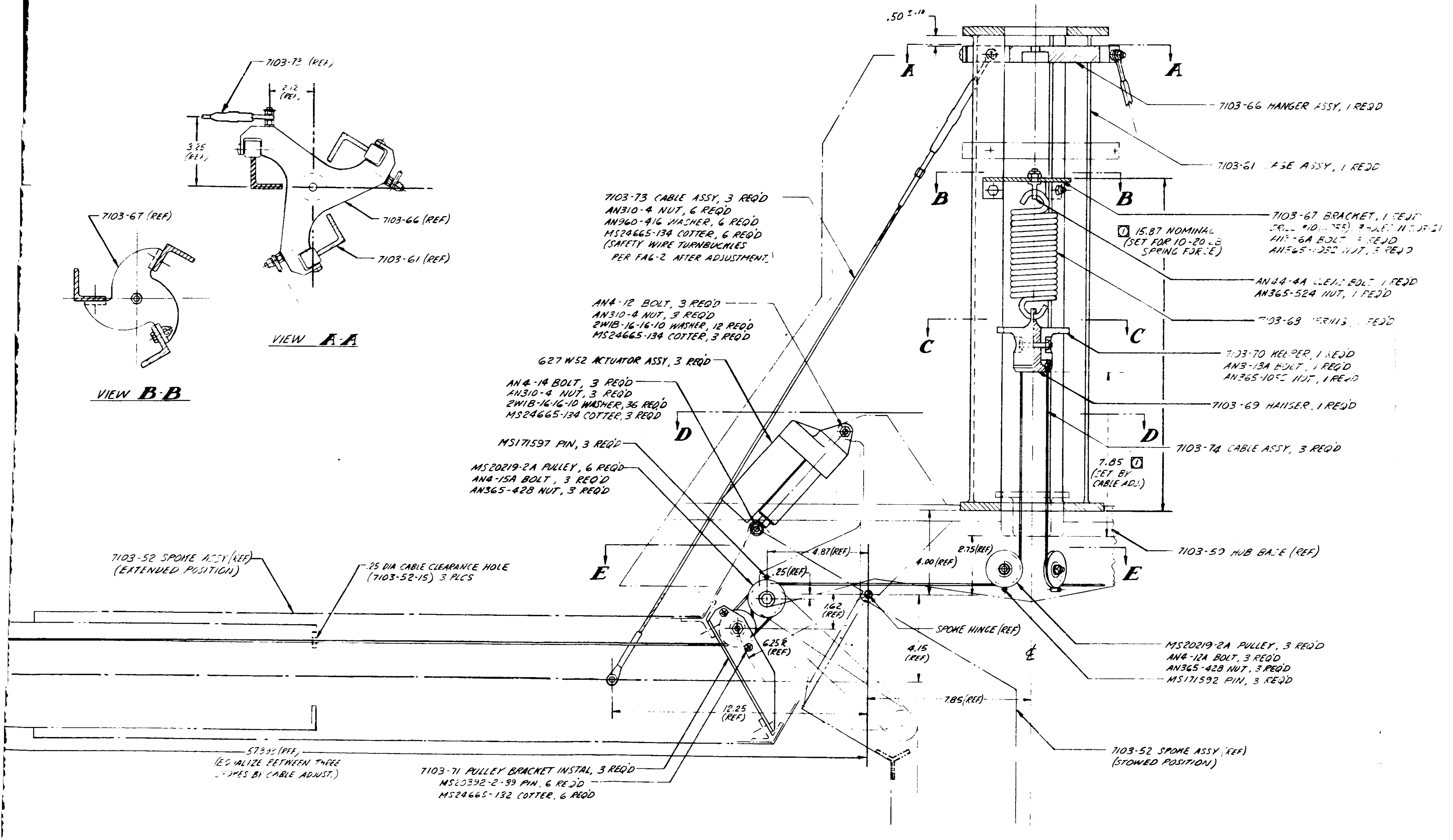
QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	SIZE	DATA: SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
					6	-13	BUSHING		SAME AS 7103-58-13		008
					6	-11	BRACKET		.38 x 4.25 x 6.25	C.R. STL PLATE COMM'L (1020)	006
					3	-9	BRACKET		.38 x 4.50 x 13.50	C.R. STL PLATE COMM'L (1020)	005
					3	-7	BRACKET		.75 x 4.50 x 6.50	C.R. STL PLATE COMM'L (1020)	004
					1	-5	BASE		.88 x 36.0 DIA	C.R. STL PLATE COMM'L (1020)	003
					1	-3	WELD ASSY		CONSISTS OF -5, -7, -9 & -11		002
					1	-1	BASE ASSY				001

LIST OF MATERIAL OR PARTS LIST

Drawing 7103-59B Base Assembly - Hub



7103-61 (REF)
AN4-12A BOLT, 3 REQ'D
AN365-428 NUT, 3 REQ'D
7103-70 (REF)
SECTION C-C
7103-52 (REF)
627 W 52 (REF)
7103-59 (REF)
7103-73 (REF)
VIEW D-D
7103-59 (REF)
7103-74 (REF)
7103-52 (REF)
7103-71 (REF)
℄ PULLEY
7103-73 (REF)
.44 (REF)
℄ SPOKE
7103-75 STUD 3 REQ'D
AN365-428 NUT, 3 REQ'D
VIEW E-E
.62 DIA CLEARANCE HOLE
(7103-52-14) 3 PLCS
.62
7103-72 (REF)
VIEW F-F
7103-72 BRACKET, 3 REQ'D
DRILL #10 (.1935), 2 HOLES (3 PLCS)
AN3-6A BOLT, 6 REQ'D
AN365-1032 NUT, 6 REQ'D
7103-76 BOLT, 3 REQ'D
AN960-10L WASHER, 3 REQ'D
F
.25
F
2.25 NOMINAL
(ADJUST AS REQUIRED)



2. INSTALL FASTNERS PER LA0101-001

1. RIGGING DATA

NOTES (UNLESS OTHERWISE SPECIFIED)

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVED
	1. MAY BE REWORKED 3. RECORD CHANGE 2. CANNOT BE REWORKED 4. NOW SHOP PRACTICE 5. PARTS MADE OK		

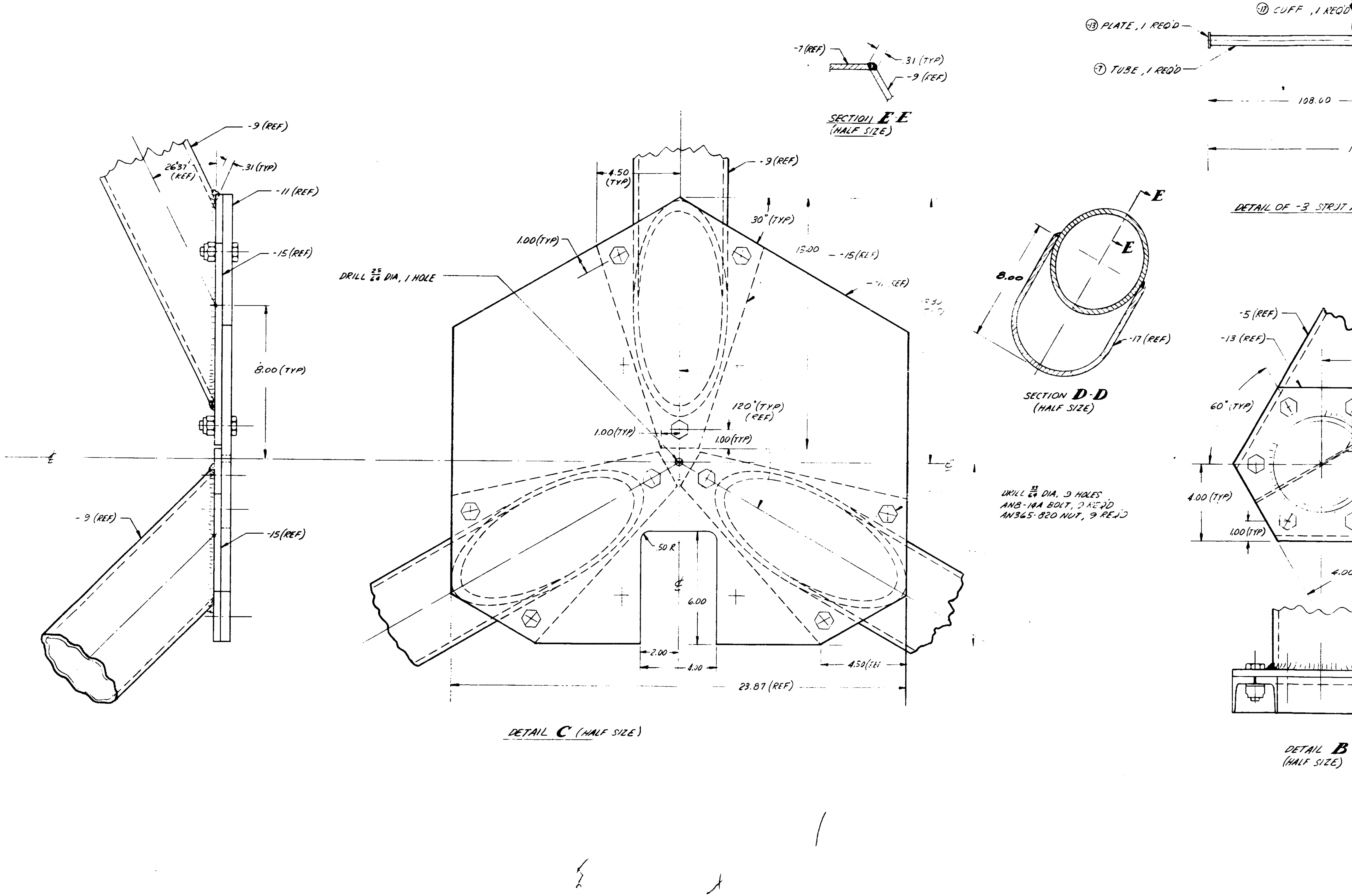
QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
					48	2W1B-16-16-10	WASHER	5			
					12	MS24665-134	COTTER	5			
					6	MS24665-132	COTTER	5			
					6	MS20392-2-39	PIN	5			
					9	MS20219-2A	PULLEY	3/5			
					3	MS171597	PIN	5			
					3	MS171592	PIN	3			
					6	AN960-416	WASHER	5			
					3	AN960-10L	WASHER	6			
					1	AN365-524	NUT	3			
					9	AN365-428	NUT	3/5/7/9			
					10	AN365-1032	NUT	3/3/6			
					12	AN310-4	NUT	5			
					1	AN44-4A	CLEVIS BOLT	3			
					3	AN4-15A	BOLT	5			
					3	AN4-14	BOLT	5			
					6	AN4-12A	BOLT	3/7			020
					3	AN4-12	BOLT	5			019
					1	AN3-13A	BOLT	3			018
					9	AN3-6A	BOLT	3/6			017
											016
											015
					3	7103-76	BOLT	6			014
					3	7103-75	STUD	9			013
					3	7103-74	CABLE ASSY	3			012
					3	7103-73	CABLE ASSY	5			011
					3	7103-72	BRACKET	6			010
					3	7103-71	PULLEY INSTAL	5			009
					1	7103-70	KEEPER	3			008
					1	7103-69	HANGER	3			007
					1	7103-68	SPRING	3			006
					1	7103-67	BRACKET	3			005
					1	7103-66	HANGER ASSY	3			004
					1	7103-61	CASE ASSY	3			003
					3	627 W 52	ACTUATOR ASSY	5		CONSOLIDATED CONTROL CORP.	002
						7103-56	INSTALLATION				001

LIST OF MATERIAL OR PARTS LIST

Drawing 7103-56 Mechanism Installation - Hub

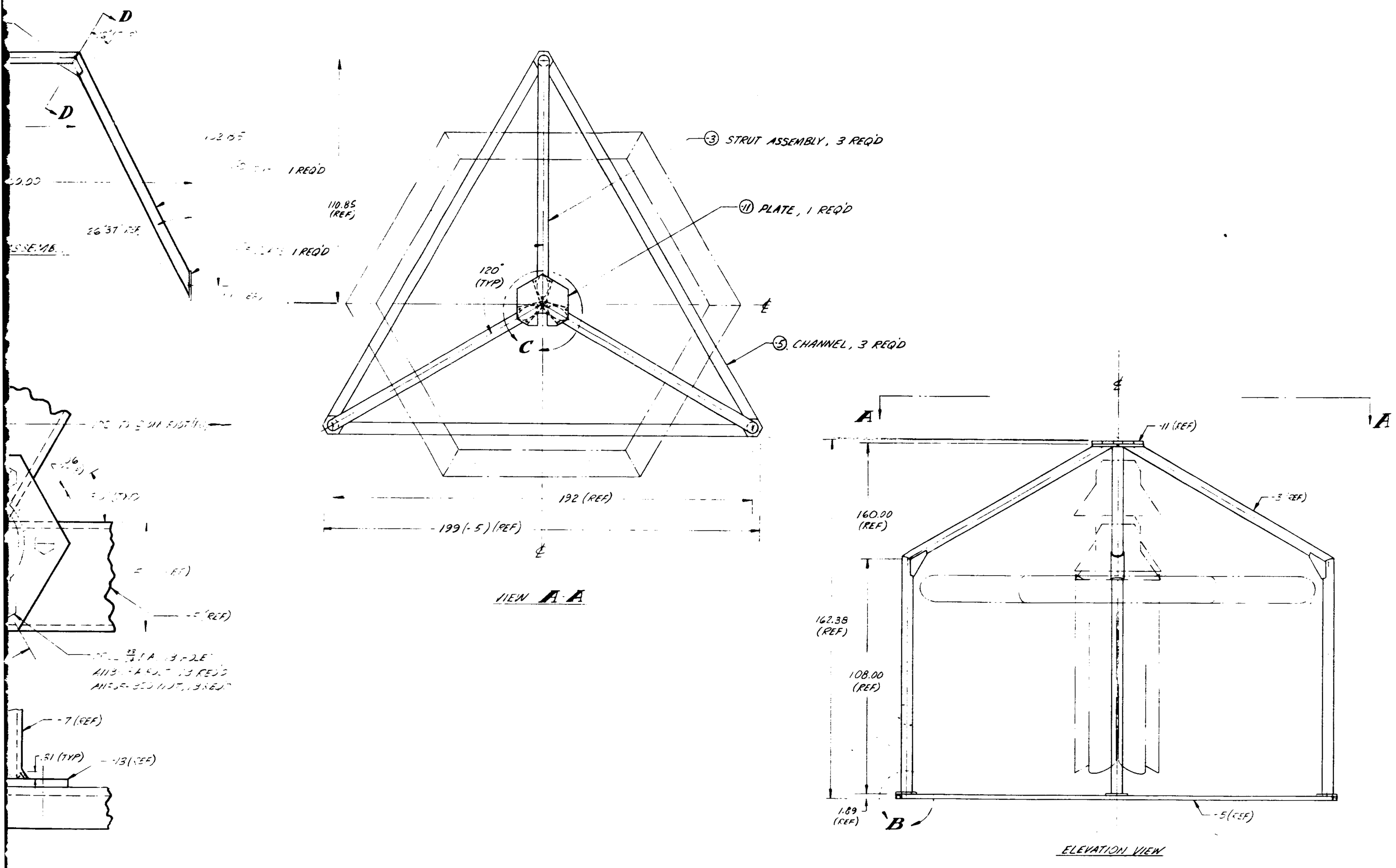
2

2



-9 (REF)
26°37' (REF)
.31 (TYP)
-11 (REF)
-15 (REF)
8.00 (TYP)
-9 (REF)
-15(REF)
DRILL 25/64 DIA, 1 HOLE
1.00(TYP)
4.50 (TYP)
-9 (REF)
30° (TYP)
13.00
-15(REF)
120°(TYP) (REF)
1.00(TYP)
1.00(TYP)
.50 R
6.00
2.00
4.00
4.50(REF)
23.87 (REF)
DETAIL C (HALF SIZE)
-7 (REF)
.31 (TYP)
-9 (REF)
SECTION E-E (HALF SIZE)
E
E
8.00
-17 (REF)
SECTION D-D (HALF SIZE)
DRILL 33/64 DIA, 9 HOLES
AN8-14A BOLT, 9 REQ'D
AN365-820 NUT, 9 REQ'D
-13 PLATE, 1 REQ'D
-17 CUFF, 1 REQ'D
-7 TUBE, 1 REQ'D
108.00
DETAIL OF -3 STRUT
-5 (REF)
-13 (REF)
60° (TYP)
4.00 (TYP)
1.00 (TYP)
DETAIL B (HALF SIZE)

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVED
	1. MAY BE REWORKED 3. RECORD CHANGE 2. CANNOT BE REWORKED 4. NOW SHOP PRACTICE 5. PARTS MADE OK		

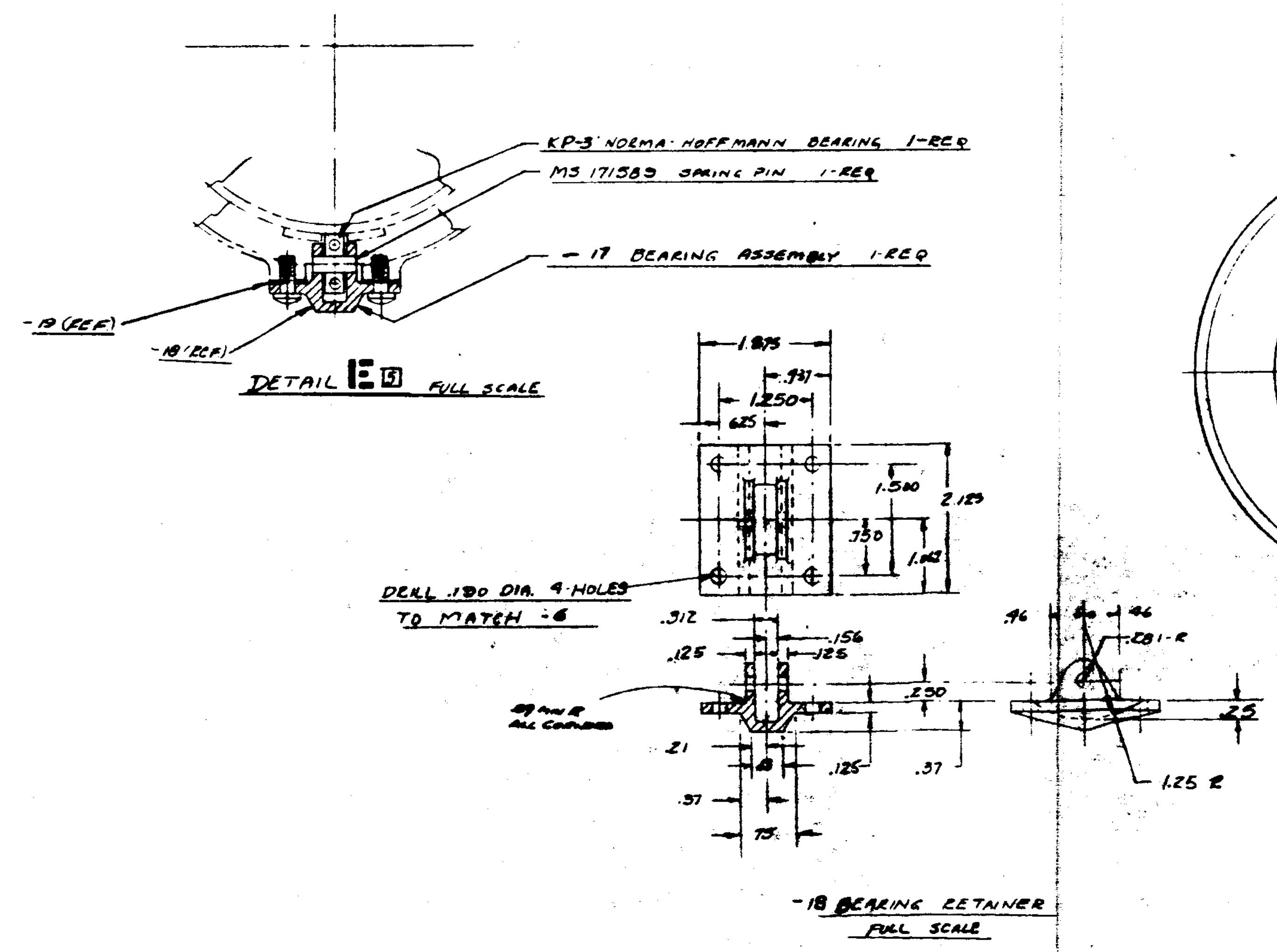


3. BREAK SHARP EDGES .030
2. TEST COMPLETE ASSY TO 5000 LB LOAD
1. WELD & MAGNETIC INSPECT -3 ASSY PER MA0107-004
NOTES (UNLESS OTHERWISE SPECIFIED)

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA: SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
											020
											019
											018
					27	AN365-820	NUT				017
					9	AN8-14A	BOLT				016
					18	AN8-13A	BOLT				015
											014
											013
											012
											011
											010
				1		-17	CUFF		LOW CARBON STL PLATE	1/4 x 12 x 20 COMMERCIAL	009
				1		-15	PLATE			1/3 x 9 x 13 COMMERCIAL	008
				1		-13	PLATE			1/3 x 8 x 3.5 COMMERCIAL	007
					1	-11	PLATE		LOW CARBON STL PLATE	1/2 x 23.5 x [illegible] COMMERCIAL	006
				1		-9	TUBE		LOW CARBON STL TUBE	[illegible]	005
				1		-7	TUBE		[illegible]	[illegible]	004
					3	-5	CHANNEL		LOW CARBON STL CHANNEL	(5 IN [illegible]) x 199 COMMERCIAL	003
					3	-3	STRUT ASSY				002
				-3		7103-54	ASSEMBLY				001

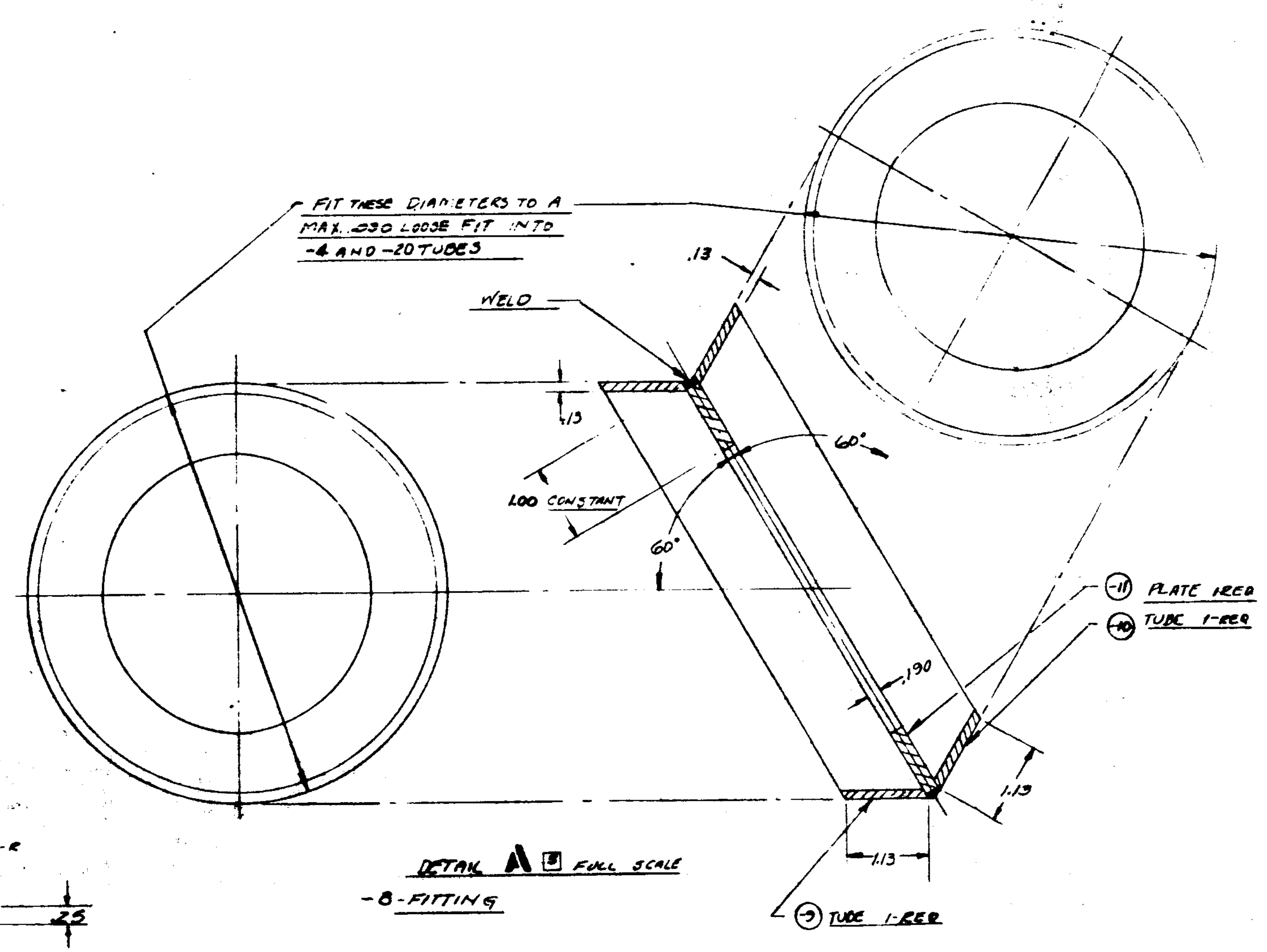
LIST OF MATERIAL OR PARTS LIST

Drawing 7103-54 Stand Assembly - Support

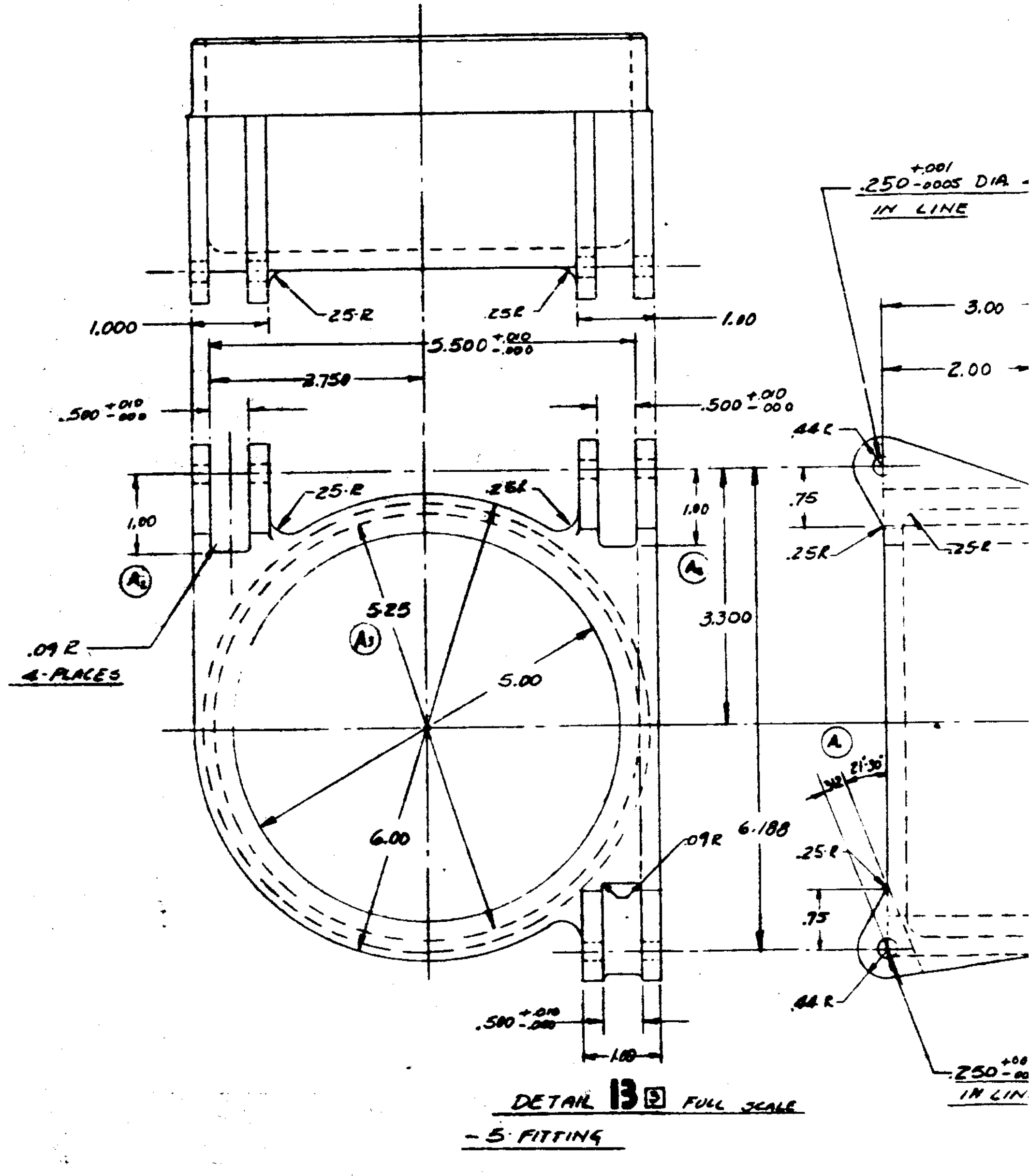


DETAIL E FULL SCALE

-18 BEARING RETAINER
FULL SCALE

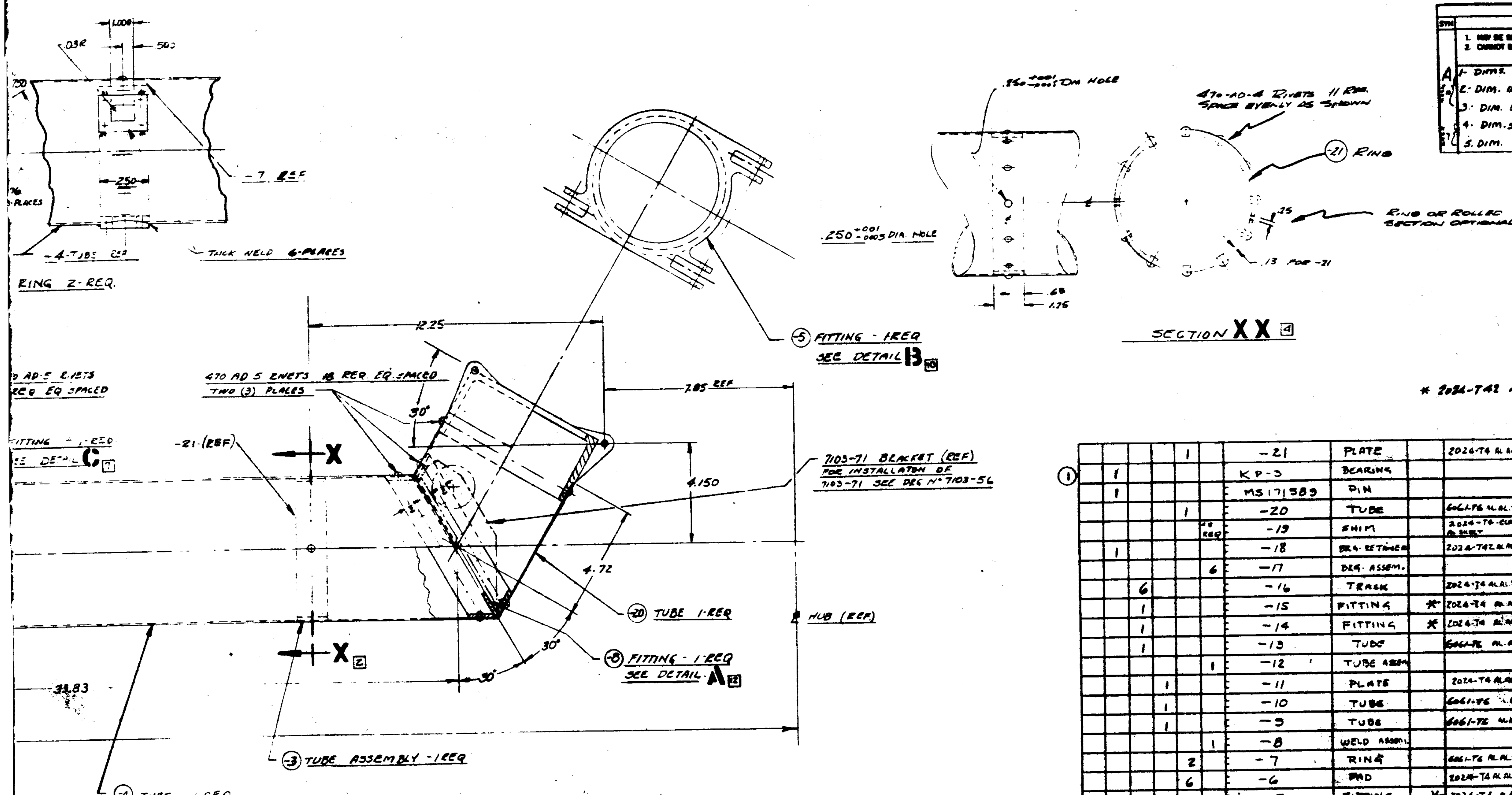


DETAIL A FULL SCALE
-8-FITTING



DETAIL B FULL SCALE
-5 FITTING

REVISIONS				
SYM	DESCRIPTION		DATE	APPROVED
	1. MAY BE REWORKED 3. RECORD CHANGE 2. CANNOT BE REWORKED 4. NOW SHOP PRACTICE 5. PARTS MADE OK			
A	1- DIMS. .312 & 21°-30' ADDED	4		
	2- DIM. .100 WAS .131 (2 PLACES)	4		
	3- DIM. 5.25 WAS 5.5	4 OR 5		
	4- DIM. .50 & 30° ADDED	4		
	5. DIM. .87 REMOVED (2 PLACES)	4	AUG-1-1960	[illegible]



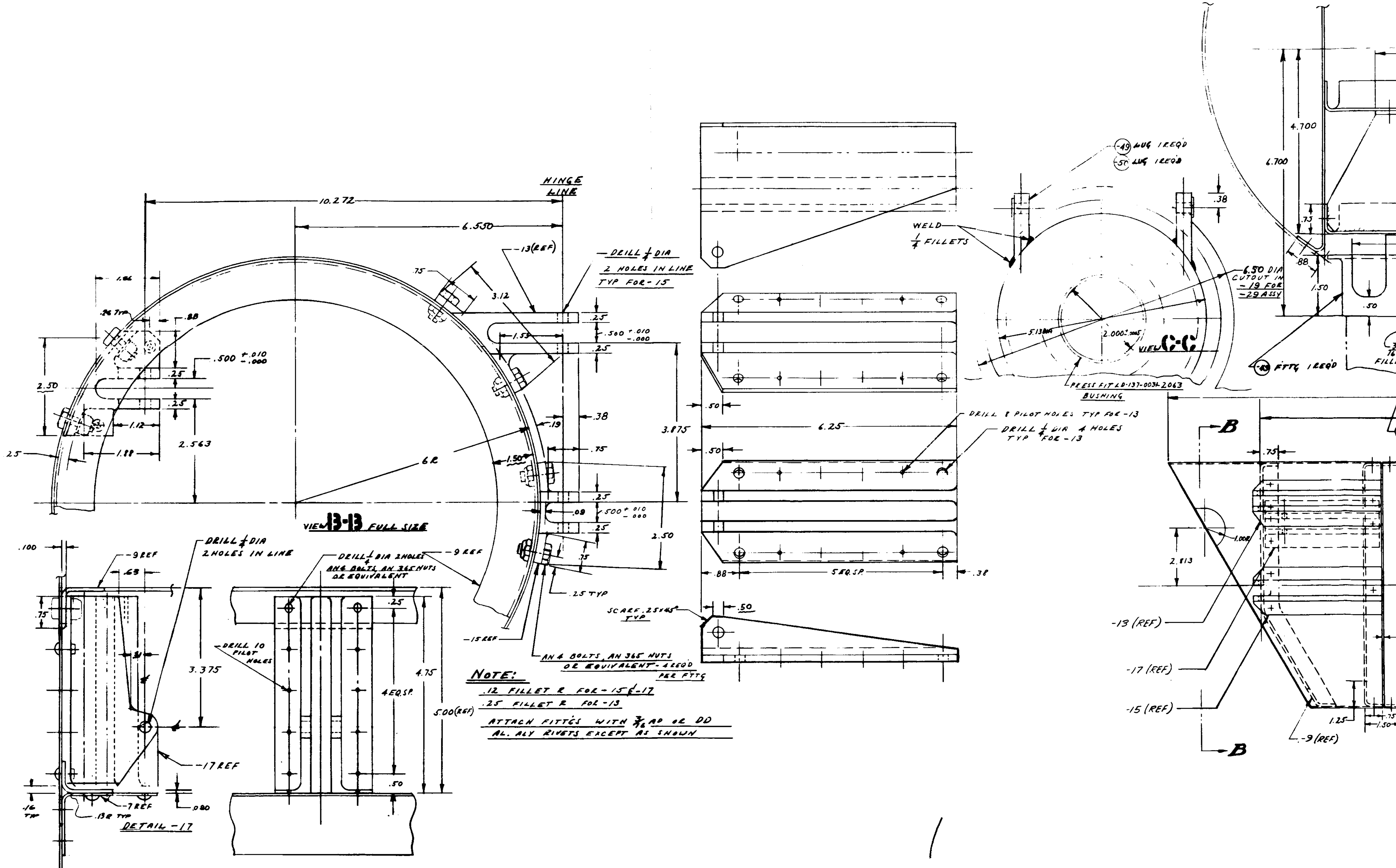
* 2024-T42 ACCEPTABLE

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA: SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
				1		-21	PLATE		2024-T4 AL AL SHEET	.187 x 1.25 x 21 QQ-A-362	
(1)	1					KP-3	BEARING			SEE NOTE (1)	
	1					MS171589	PIN				020
				1		-20	TUBE		6061-T6 AL AL TUBE	6" O.D. x .058 WALL x 7 LONG WW-T-787	019
					AS REQ	-19	SHIM		2024-T4 CLAD AL AL SHEET	SPEC QQ-A-362 TEMP-4	018
	1					-18	BRG. RETAINER		2024-T42 AL AL SHEET	1 x 1 3/8 x 2 QQ-A-267 TEMP T42	017
					6	-17	BRG. ASSEM.				016
		6				-16	TRACK		2024-T4 AL AL SHEET	.050 x 1/2 x 25 QQ-A-362	015
		1				-15	FITTING	*	2024-T4 AL AL SHAPE	1 1/2 x 5 x 5 QQ-A-267 TEMP-T42	014
		1				-14	FITTING	*	2024-T4 AL AL SHAPE	3 1/4 x 5 x 5 3/4 QQ-A-267 TEMP. T42	013
		1				-13	TUBE		6061-T6 AL AL TUBE	5" O.D. x .125 WALL x 25 LONG WW-T-787	012
					1	-12	TUBE ASSEM				011
			1			-11	PLATE		2024-T4 AL AL SHEET	.250 x 6 x 7 QQ-A-362	010
			1			-10	TUBE		6061-T6 AL AL TUBE	6 O.D. x .188 WALL x 4 1/2 LONG WW-T-787	009
			1			-9	TUBE		6061-T6 AL AL TUBE	6 O.D. x .188 WALL x 4 1/2 LONG WW-T-787	008
					1	-8	WELD ASSEM.				007
				2		-7	RING		6061-T6 AL AL TUBE	4 1/2 O.D. x .250 x 3/8 WW-T-787	006
				6		-6	PAD		2024-T4 AL AL SHEET	3/8 x 2 x 2 1/2 QQ-A-362	005
				1		-5	FITTING	*	2024-T4 AL AL SHAPE	3 1/2 x 6 x 7 QQ-A-267 TEMP-T42	004
				1		-4	TUBE		6061-T6 AL AL TUBE	6 O.D. x .058 WALL x 36 LONG WW-T-787	003
					1	-3	TUBE ASSEM				002
	-17	-12	-8	-3	BASIC		SPOKE ASSEM.				001
LIST OF MATERIAL OR PARTS LIST											

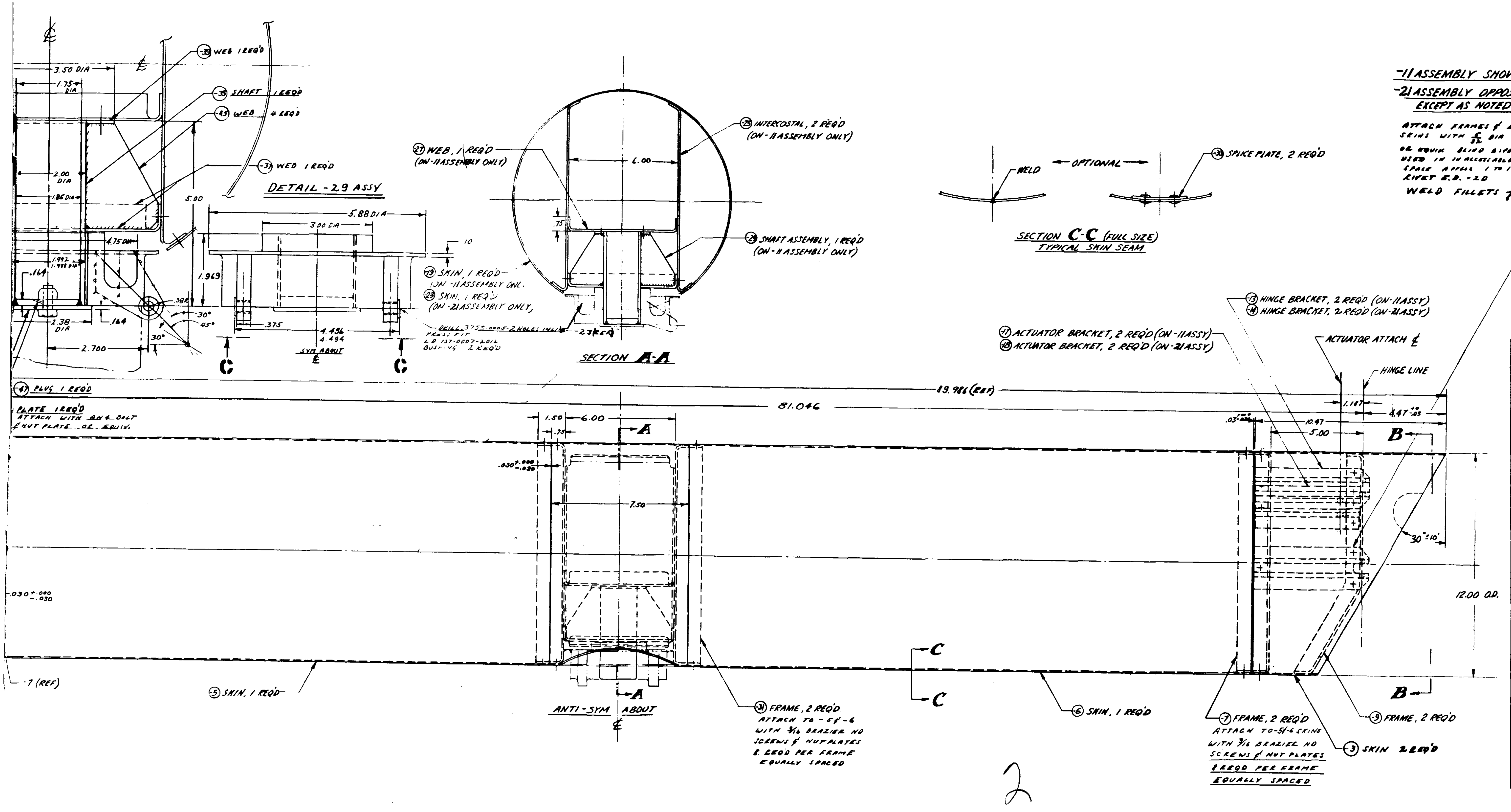
NOTES (1) NORMA-HOFFMANN BEARING MAY BE PURCHASED FROM HAROLD SWANTON INC 325 W. 17th ST. LOS ANGELES CALIF.

Drawing 7103-52A Assembly - Spoke

3



VIEW B-B FULL SIZE
VIEW C-C
DETAIL -17
HINGE LINE
DRILL 1/4 DIA 2 HOLES IN LINE TYP FOR -15
DRILL 1/4 DIA 2 HOLES IN LINE
DRILL 1/4 DIA 2 HOLES & AN4 BOLTS, AN 365 NUTS OR EQUIVALENT
DRILL 10 PILOT HOLES
DRILL 8 PILOT HOLES TYP FOR -13
DRILL 1/4 DIA 4 HOLES TYP FOR -13
AN 4 BOLTS, AN 365 NUTS OR EQUIVALENT - 4 REQ'D PER FTTG
SCARF .25 X 45° TYP
WELD 1/4 FILLETS
-49 LUG 1 REQ'D
-50 LUG 1 REQ'D
-48 FTTG 1 REQ'D
6.50 DIA CUTOUT IN -19 FOR -29 ASSY
PRESS FIT LD-137-0034-2063 BUSHING
NOTE:
.12 FILLET R FOR -15 & -17
.25 FILLET R FOR -13
ATTACH FITTGS WITH 3/16 AD OR DD AL. ALY RIVETS EXCEPT AS SHOWN
-13 (REF)
-17 (REF)
-15 (REF)
-9 (REF)



REVISIONS

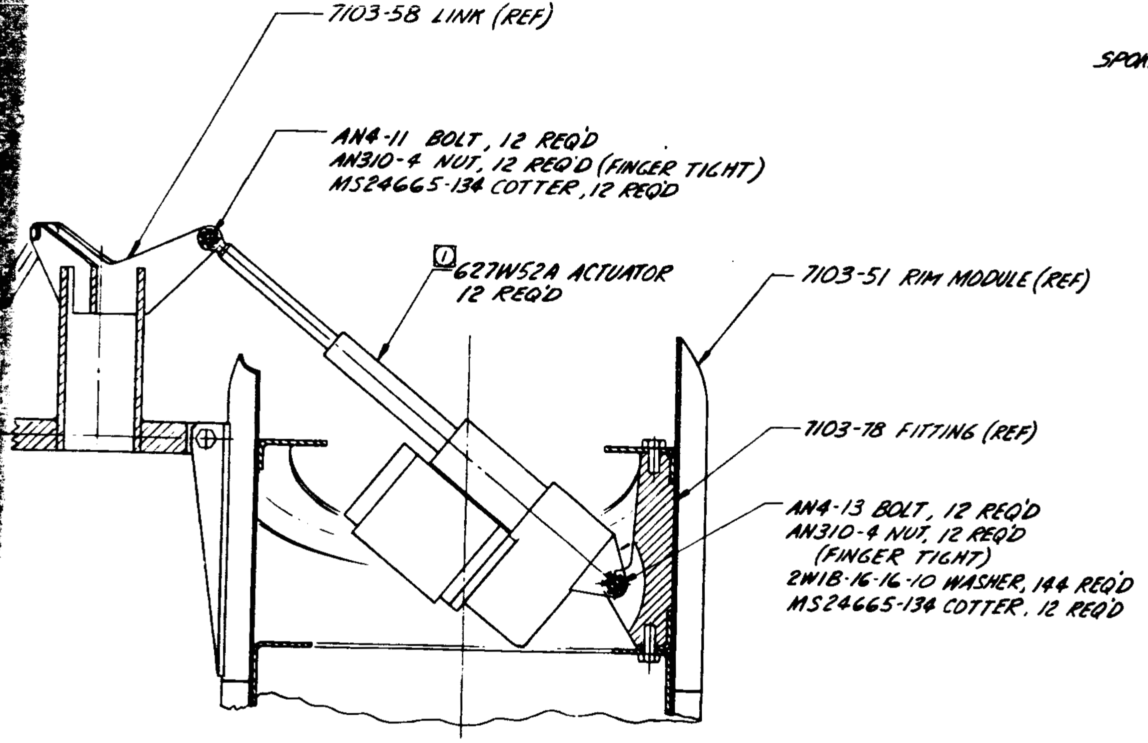
SYM	DESCRIPTION	DATE	APPROVED
	1. MAY BE REWORKED 2. CANNOT BE REWORKED 3. RECORD CHANGE 4. NOW SHOP PRACTICE 5. PARTS MADE OK		

CHANGE A. Removed -17 fitting. Added note See Removal Dwg. 7103-?? for fitting & its attachment.

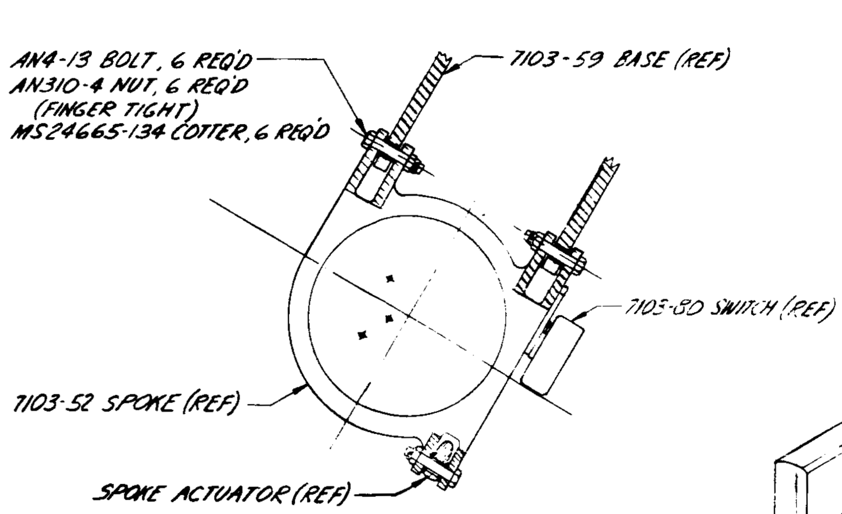
QTY REQD	QTY REQD	QTY REQD	QTY REQD (-29 SUB ASSY)	QTY REQD (-21 ASSY)	QTY REQD (-11 ASSY)	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA: SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
			1			-50	LUG		LOW CARBON STEEL PLATE COMM'L	7/16 x 4 x 4	
			1			-49	LUG		LOW CARBON STEEL PLATE COMM'L	7/16 x 4 x 4	
			1			-47	PLUG		LOW CARBON STEEL SHT. COMM'L	.164 x 1 3/4 DIA	
			4			-45	WEB		LOW CARBON STEEL SHEET COMM'L	.090 x 4 x 6	
			1			-43	FTTG		LOW CARBON STEEL ROUND	2 x 6 1/2 DIA	
			1			-41	PLATE		LOW CARBON STEEL SHEET COMM'L	.164 x 2 3/4 DIA	
			1			-39	WEB		LOW CARBON STEEL SHT. COMM'L	.090 x 3 1/2 DIA	
			1			-37	WEB		LOW CARBON STEEL SHT. COMM'L	.083 x 8 x 8	
			1			-35	SHAFT		LOW CARBON STEEL, CD SEAMLESS TUBING	.134 x 2 1/8 DIA x 5 1/4	020
				2	2	-33	SPLICE		6061 T6 AL. ALY SHT	.063 x 3 x 31	019
				2	2	-31	FRAME		6061 T6 AL ALY SHT	.063 x 42 x 42	018
					1	-29	SUB-ASSY				017
					1	-27	WEB		6061 T6 AL ALY SHT	.063 x 8 x 8	016
					2	-25	INTERCOSTAL		6061 T6 AL ALY SHT	.063 x 9 x 13	015
				1		-23	SKIN		6061 T6 AL. ALY SHT	.040 x 8 x 38	014
					1	-19	SKIN		6061 T6 AL ALY SHT.	.040 x 8 x 38	013
				2		-18	BRACKET		2024 T42 AL. ALY BAR	2 1/2 x 2 1/2 x 5	012
					2	-17	↑		↑	2 1/2 x 2 1/2 x 5	011
				2		-16				1 1/4 x 2 1/2 x 6 1/4	010
					2	-15				1 1/4 x 2 1/2 x 6 1/4	009
				2		-14	↓		↓	2 1/2 x 4 x 6 1/4	008
					2	-13	BRACKET		2024 T42 AL ALY BAR	2 1/2 x 4 x 6 1/4	007
				2	2	-9	FRAME		6061 AL ALY SHT	.100 x 18 x 18	006
				2	2	-7	FRAME		6061 AL ALY SHT	.063 x 18 x 18	005
				1	1	-6	SKIN		6061 T6 AL. ALY SHT	.040 x 31 x 38	004
				1	1	-5	SKIN		6061 T6 AL ALY SHT	.040 x 31 x 38	003
				2	2	-3	SKIN		6061 T6 AL. ALY SHT.	.050 x 11 x 38	002
			-29	-21	-11	7103-51	ASSEMBLY				001

LIST OF MATERIAL OR PARTS LIST

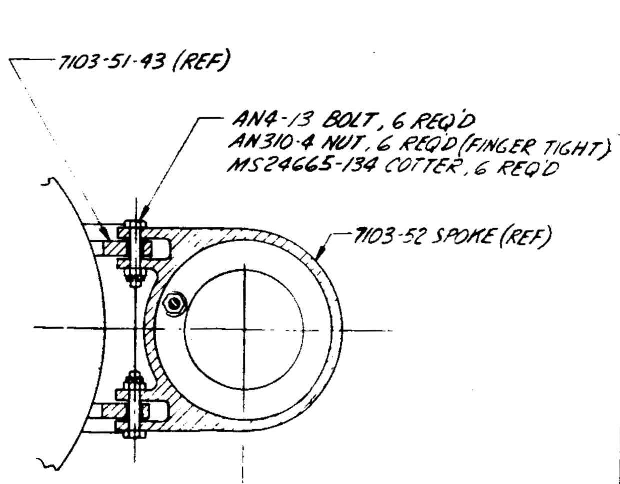
Drawing 7103-51A Rim - Module Assembly



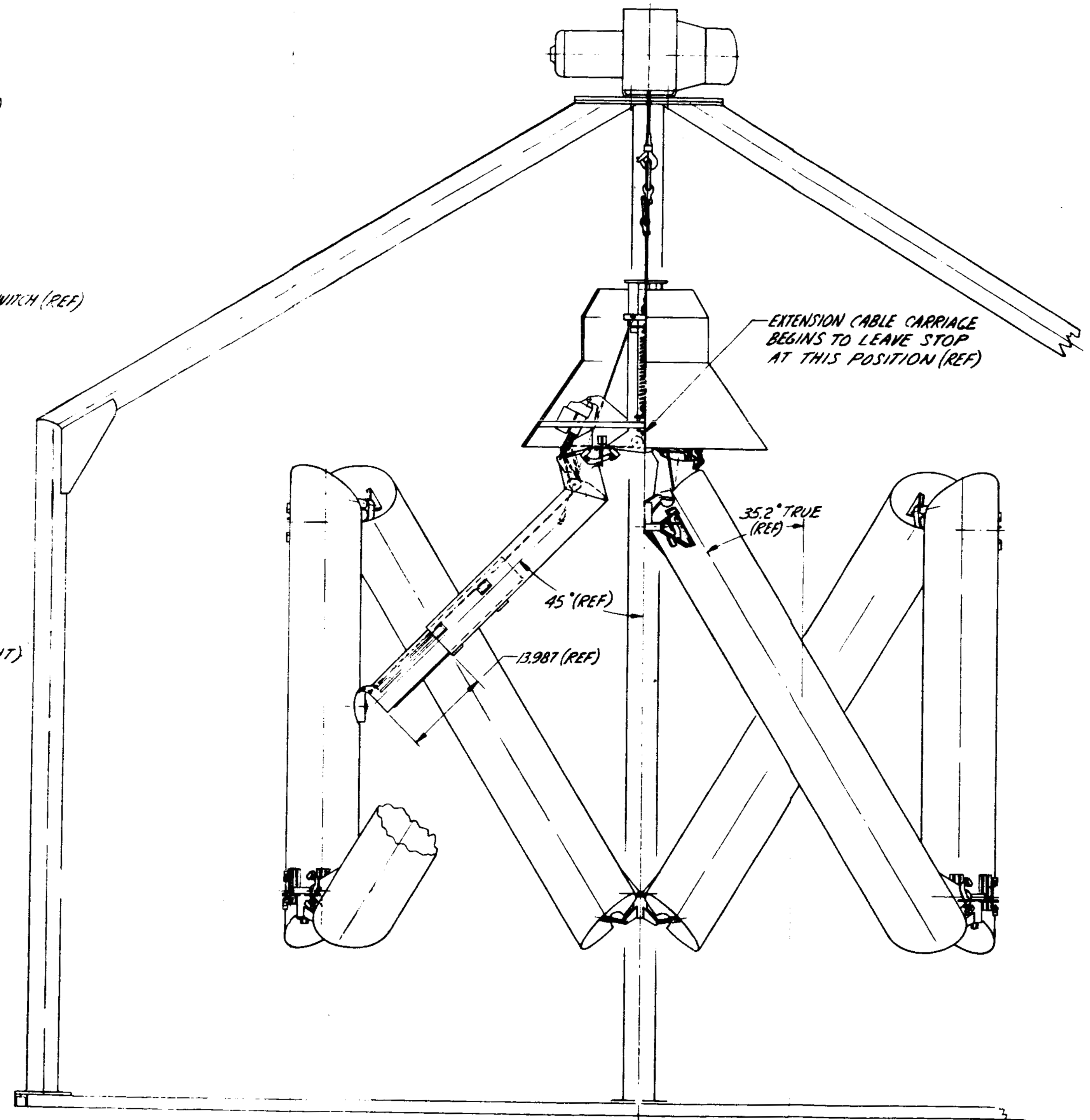
SECTION D-D (HALF SIZE)
TYPICAL TWELVE PLACES



SECTION B-B (HALF SIZE)
TYPICAL THREE PLACES



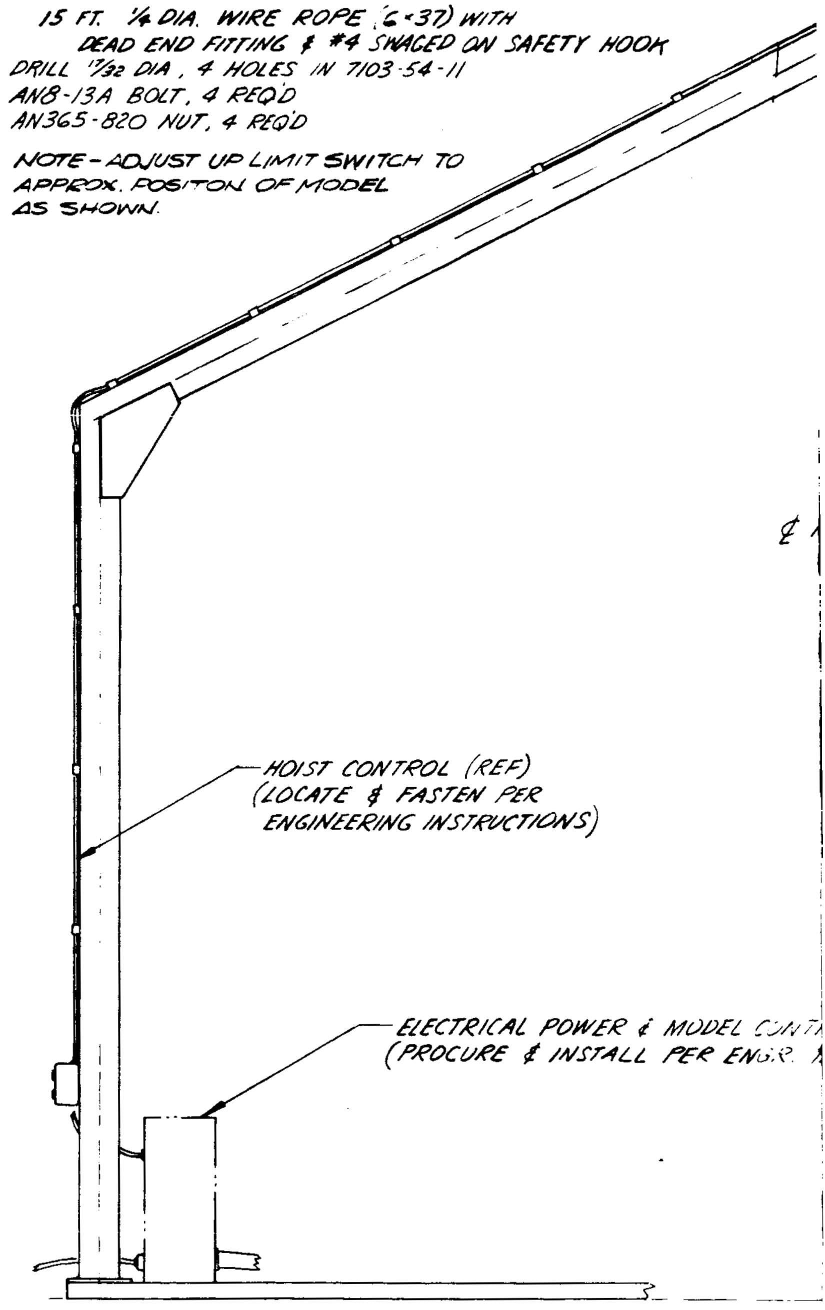
SECTION C-C (HALF SIZE)
TYPICAL THREE PLACES



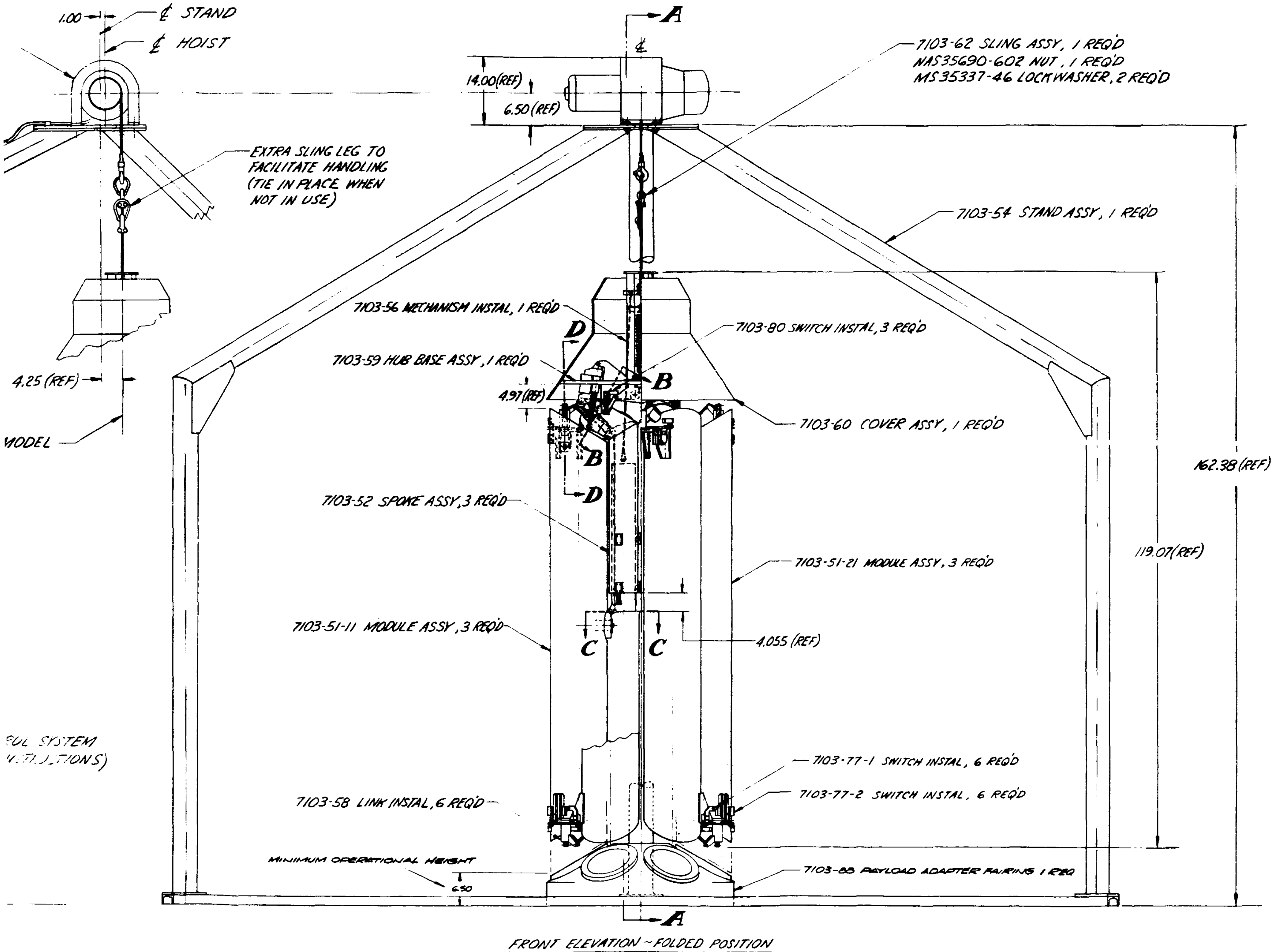
FRONT ELEVATION-PARTIALLY EXTENDED (45° SPOKE) POSITION

② WRIGHT SPEEDWAY BS8432 ELECTRIC HOIST, 1 REQ'D –
34 FPM SINGLE SPEED 220 V 3 PH 60 CYCLE BASE MOUNTED
TO BE PROCURED WITH:
MOMENTARY CONTACT TWO STATION PUSH BUTTON
CONTROL & 18 FT FLEXIBLE CONTROL CABLE
UPPER LIMIT SWITCH
15 FT. 1/4 DIA. WIRE ROPE (6×37) WITH
DEAD END FITTING & #4 SWAGED ON SAFETY HOOK
DRILL 17/32 DIA, 4 HOLES IN 7103-54-11
AN8-13A BOLT, 4 REQ'D
AN365-820 NUT, 4 REQ'D

NOTE – ADJUST UP LIMIT SWITCH TO
APPROX. POSITION OF MODEL
AS SHOWN.



SECTION A-A



REVISIONS			
SYM	DESCRIPTION	DATE	APPROVED
	1. MAY BE REWORKED 3. RECORD CHANGE 2. CANNOT BE REWORKED 4. NOW SHOP PRACTICE 5. PARTS MADE OK		

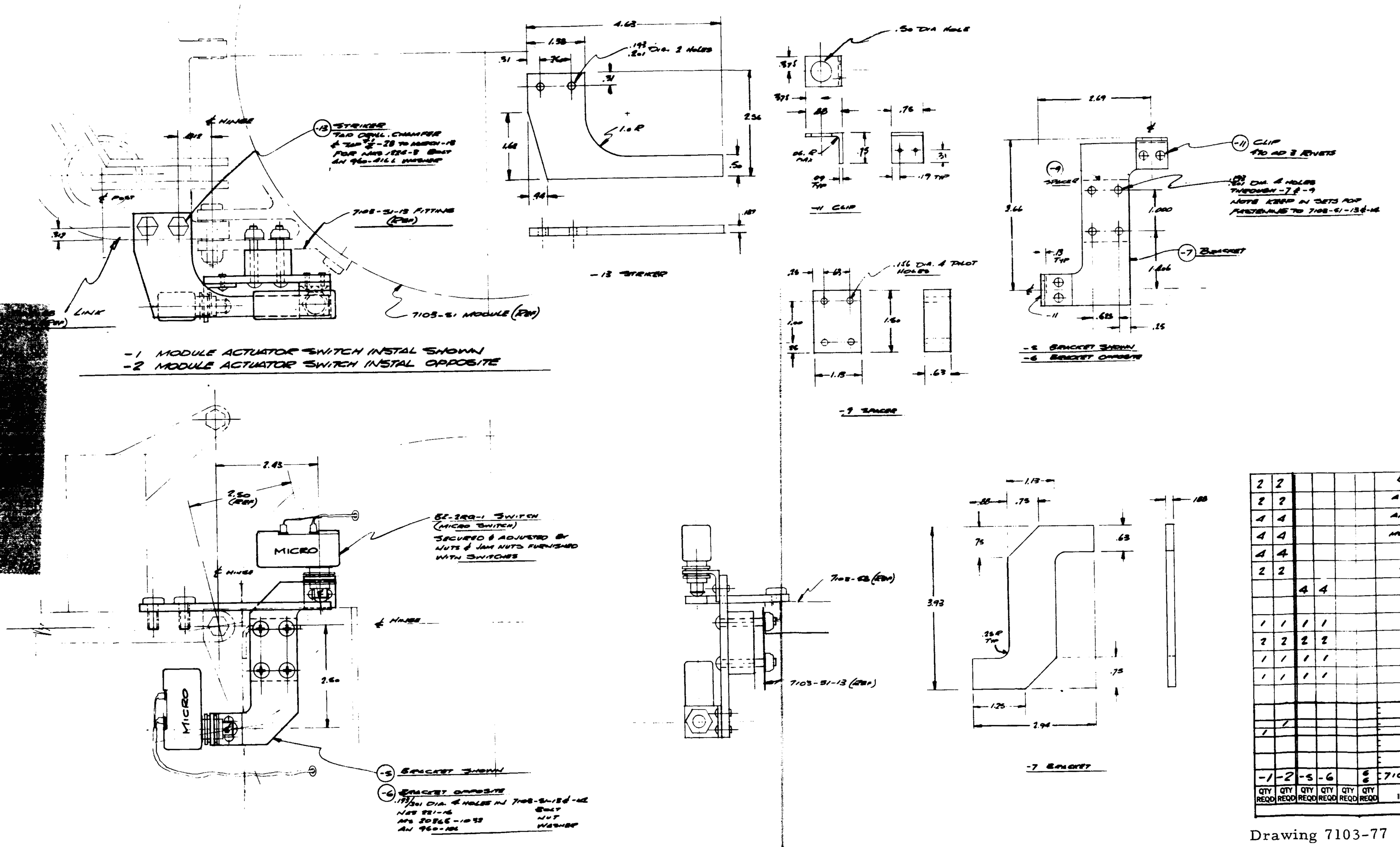
3. LUBRICATE ALL HINGE JOINTS WITH LIGHT CUP GREASE LUBRICATE HOIST & ACTUATORS PER MFG.'S INSTRUCTIONS
2. WRIGHT HOIST DIVISION OF AMERICAN CHAIN & CABLE CO. YORK, PA. (SEE DWG CALLOUT FOR COMPLETE REQUIREMENT)
1. CONSOLIDATED CONTROLS CORP, INGLEWOOD, CALIF.
NOTES (UNLESS OTHERWISE SPECIFIED)

	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA: SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
						144	2W18-16-16-10	WASHER				
						1	MS35690-602	NUT				
						2	MS35337-46	LOCKWASHER				
						36	MS24665-134	COTTER PIN				
						4	AN365-820	NUT				
						36	AN310-4	NUT				
						4	AN8-13A	BOLT				
						24	AN4-13	BOLT				
						12	AN4-11	BOLT				
												020
												019
												018
												017
2						1	BS8432	HOIST				016
1						12	627W52A	ACTUATOR				015
												014
												013
												012
						1	7103-88	ADAPTER FAIRING				011
						1	7103-62	SLING ASSY				010
						1	7103-60	HUB COVER ASSY				009
						1	7103-59	HUB BASE ASSY				008
						6	7103-58	LINK INSTAL				007
						1	7103-56	MECH. INSTAL				006
						1	7103-54	STAND ASSY				005
						3	7103-52	SPOKE ASSY				004
						3	7103-51-12	RIM MODULE				003
						3	7103-51-11	RIM MODULE				002
							7103-50	ASSEMBLY				001

LIST OF MATERIAL OR PARTS LIST

Drawing 7103-50 Complete Assembly

2



QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA: SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
2	2					BZ-2RQ-1	MICRO SWITCH		HONEYWELL (CATALOGUE 62)		
2	2					AN 960-416L	WASHER				
4	4					AN 960-10L	WASHER				
4	4					MS 20365-1032	NUT				
4	4					NAS 221-22	BOLT				
2	2					NAS 1224-3	BOLT				
		4	4			470 AD-3	RIVET				
1	1	1	1			-13	STRIKER		2024-T4 AL ALLOY PLATE (COMM'L)	3/16 × 2 9/16 × 4 5/8	
2	2	2	2			-11	CLIP		2024-T4 AL ALLOY EXTRUSION (COMM'L)	7/8 × 7/8 × 1/4 ANGLE	
1	1	1	1			-9	SPACER		2024-T4 AL ALLOY BAR (COMM'L)	5/8 × 1 1/8 × 1 1/2	
1	1	1	1			-7	BRACKET		2024-T4 AL ALLOY PLATE (COMM'L)	3/16 × 2.94 × 3.94	
											005
	1					-6	BRACKET	OPP	CONSISTS OF -7, -9 & -11		004
1						-5	BRACKET	SHOWN	CONSISTS OF -7, -9 & -11		
											003
											002
-1	-2	-5	-6		6 6	7103-77 -2 -1	INSTALLATION OPPOSITE INSTALLATION SHOWN				001

LIST OF MATERIAL OR PARTS LIST

Drawing 7103-77 Switch Installation - Module Actuator

II. PROBLEM AREAS

During the six-month feasibility study, several problem areas in the design and development of the SDSS were foreseen. These problems do not detract from the feasibility of the concept; they are simply pointed out as areas that will require a greater-than-average amount of attention in the early phases of a development program. In a number of cases, a problem area has been so defined primarily because of a lack of data on that area or because design detail has not developed to a point where a decision could clearly be made on an optimum solution. The problems discussed herein are grouped according to major technical areas.

VEHICLE DESIGN

APOLLO DOCKING

The Apollo Spacecraft Design group has already considered docking from the standpoint of vehicle requirements. Sealing of the Apollo to an airlock, the clearance of a hinged cover exposing the exit port, and certain aspects of vehicle lock-on have been investigated.

The exact design of a mating dock to coordinate with Apollo is incomplete. A bellows that would embody the features of a flexible interface may be possible. A design should be worked out based on velocity criteria of the closing phase of rendezvous, with emphasis on a dock adapter that will accept the vehicle with some residual angle, translation, and closing velocity.

ZERO-GRAVITY DOCKING TURRET

A turret structure capable of being de-spun to zero space acceleration should be investigated from the standpoint of elements which hold the turret in concentric position over a pressurized hub without constraining the turret. Rollers, if used, must roll on a raceway that is not sensitive to changes in the diameter of a hub caused by pressure changes inside the hub. Concentricity of motion must be held to an order sufficient for passage/dock matching after turret spin-up.

The materials used in the drives and the driven structure must be compatible (i.e., they must not weld together in an orbital environment). Consideration should be given to the design of a shielded docking facility or a completely enclosed logistics vehicle repair facility if the need for these is established.

BOOM BEARINGS AND DRIVES

The same problems of material and passage/dock matching that apply to the turret apply to the Apollo stowing booms. These booms must coordinate at a sealed interface with a central dock at the top of the turret for incoming Apollo logistics vehicles. They must also coordinate at the side stowing locations on the turret in order to permit a sealed passage way to be made between the space station hub and the Apollo logistics vehicle. Drives, of course, must be operable in the station environment.

HUB-TO-MODULE CONNECTIONS

The folded modules transmit the structural loads to the interstage structure between the space station and the S-II. Rigid connections hold the modules together and hold the hub of the space station securely on top of the cluster. The release of all connections should be a coordinated operation and must occur without causing damage to the structure of the space station.

The use of explosive studs and the use of initiators to free latches must be investigated to ascertain which release mechanism will be most suitable and reliable.

SPOKE EXTENSION

As deployment occurs, the modules form a symmetrical pattern at any instant. The spokes must extend at a precise rate to match the expanding rim and to avoid restraint of the deploying symmetrical system.

The 1/10-scale deployment model uses a system of cable payout to hold the spokes at the correct length. In this system, the cable always carries the weight of the modules. In deploying the space station in a zero-gravity environment, no forces except the inertia of the structural elements and the friction between connections will be encountered by the deployment mechanism. The deployment of the space station must, therefore, be positively controlled. Such a control may be obtained through the use of programmed gear drives. Alternatively, a drive with a continuous reference to the symmetry of the space station can be used.

FINAL SPOKE ADJUSTMENT

The conclusion of deployment and the latch-out of modules could be hampered if the spokes became tight tie rods prior to the completion of the flare-out. In such a situation, excessive module actuation forces could occur, either because of a poorly-adjusted spoke out stop or because of a spoke-extension drive being out of time stroke.

To avoid such a geometric stall, spokes would likely be driven only to a position where module actuation could safely take over the extension, leaving an excess of travel freedom at maximum extension, and final contraction at latch-out. Concentricity of the hub could later be secured by adjustment of spoke lengths to preload them to geometric symmetry.

EXTENDED SPOKE SEAL

In the basepoint configuration, the spokes are open ended and, therefore, unpressurized until deployment is complete. Living atmosphere is not introduced until the airlock doors on the other side of the interfaces admit it. The rigging of spoke travel so that precise lengths are achieved only after deployment means, then, that face seals at the spoke extension joint cannot be used because the exact extent of final travel is not known.

Diametrical seals appear to solve this problem, except that such seals, if they are positive, must be squeezed between the elements they seal. Such squeezing could conceivably create sufficient force in the spoke to resist extension. A seal of this nature that would only be squeezed by annular shoulders near the end of travel still produces resistance to extension or contraction at a critical period; in short, seal squeeze prior to complete deployment appears very undesirable.

Because latent seal squeeze tends to roll and damage the gland, some means of after-deployment activation appears necessary. This should occur, however, prior to admittance of pressure. It is possible that a pressure source could swell a tubular gland and be locked in to produce permanent squeeze and a qualified atmospheric seal.

SPOKE SWIVEL SEAL

Because the pressure door is in the tubular passage, tubular passage must remain connected to the spokes in three of the six modules as the modules rotate 90° and pressure must be retained across the differential rotation.

If a squeeze-type diametrical seal or a V packing gland were used, its resistance to rotation would exert a very high force on the moving components, particularly the spoke. Some sort of lip-type gland which seals on its own pressure may satisfy the function.

The real urgency of this problem appears to be the producing of a relaxed-type seal that meets the general, stiff station-seal requirement.

EQUIPMENT SUPPORT CONNECTIONS

Removal of equipment and furnishings from the proximity of any internal wall of a living area pressure tank appears necessary from the standpoint of leak repair. Furthermore, the option of not being required to locate supports at frame and stringer locations only, would permit idealized interior installations.

Allowing such freedom would require an extensive investigation into a general bolt insert design, which would take full advantage of the structural possibilities present in double-wall honeycomb pressure vessels. Not to do this could doubtless expose living atmosphere to multiple leaks due to fatigue and questionable strength margins.

SOLAR PANELS

Boosting a payload with fragile external solar arrays secured to the stacked modules presents hazards to both the arrays and the structure they are secured to.

This problem appears significant because of the high weight that could be required to ensure reliability if adroit design methods are not employed.

STABILIZATION AND CONTROL

RENDEZVOUS

It is not known what requirements the rendezvous maneuver would place upon the space station. The wobble-damping system must be able to dampen any disturbances caused by the impact of the Apollo vehicle for the purpose of the self deploying space station study, which assumed that the maximum docking error that would be encountered is about 20 inches. However, no evidence exists to substantiate this choice. Information would be available from the Gemini and Apollo programs in the near future.

DOCKING

The first docking demonstration for Gemini is awaited. The detail design of the supply vehicle stowing carriage and the control system requirements will be affected. Excessive docking impact velocities would be very difficult to design for.

SPECIFICATIONS

A wobble-damping requirement from human factors considerations should be determined. It will also be necessary to determine if there are any vehicle pointing accuracy (attitude) requirements other than those imposed by the power generation system and supply vehicle docking considerations.

SEQUENCE OF OPERATIONS

The sequence of operations from orbit injection to spin-up should be defined.

VEHICLE FLEXIBILITY FORCING FUNCTIONS

These functions – vehicle response, stability effects (on automatic systems, damping through structural energy dissipation), structural fatigue, and human factors – must be defined to proceed with a detailed system analysis.

INITIAL SOLAR ACQUISITION

It is not known whether a pilot-controlled maneuver would provide satisfactory initial orientation of the space station with respect to the sun. Even if the pilot can perform this function, satisfactory trade-off studies should be made of the desirability of including some type of automatic system as either a primary or a secondary mode of operation.

PREBOOST BALANCE

A method for obtaining suitable static and dynamic balance of the station prior to launch needs to be determined.

HUMAN FACTORS

The major human factors problem is the manning and training requirements for the space station personnel. Non-Apollo qualified crews will probably form part of the early SDSS crews. Study should be initiated at an early date to define the selection and training requirements for these personnel. Particular attention should be given to facility and training simulator requirements in that these items should be available well in advance of SDSS activation.

A space station simulation facility, such as currently under study by S&ID, should be of value in solidifying the type of research and additional facilities needed in support of the SDSS development program.

Research should be initiated immediately to determine easy-to-use techniques that will desensitize people to rotation for a predictable duration.

A better description of the scientific or other missions planned for the SDSS would permit a better job being done on the manning and training requirements study.

STRUCTURES

The following loading environment should be further investigated:

1. Boosting trajectories for the Saturn C-5 configuration with the space station payload. Time history of maximum dynamic pressure, inertia load factors, altitude and corresponding temperature environment data are necessary for a more optimized packaged design.

2. Increasing development loads for the optimized kinematics system.

3. Study of Apollo docking loads.

4. Study of the space station weight contents.

In addition to the loading environment, a number of other factors related to the structural analysis should be given additional emphasis. These include:

1. Study of the stiffness criteria of the space station during boost, orbital flight, etc.

2. Analysis of the support arrangement connecting the modules to the thrust structure and central hub to select the optimum design of the space station in the packaged configuration.

3. More detailed analysis of support arrangement of the docking turret after loads criteria is established.

4. Conducting weight trade-off studies of the module joints to select the recommended design.

5. Performing additional work on meteoroid penetration phenomena to further refine the meteoroid bumper.

COMMUNICATION SYSTEM

DELINEATION OF EXPERIMENTAL PAYLOAD

The major portion of the communication system capability will be utilized in transferring the experimental data to using agencies on earth. The availability of information concerning the experimental data would therefore facilitate the operations planning and the communication system design. Interesting features of the data are: format (analog or digital) bandwidth (or bit rate), duty cycle, required accuracy, signal level, and urgency of delivery.

ON-BOARD PROCESSING

The space station is expected to have diverse experiments requiring varying amounts of on-board processing. Some data will require only storage, whereas other experiments will require on-board data editing, compaction, and even complete reduction. An investigation should be conducted to ascertain the effectiveness of various on-board data processing schemes in enhancing the overall capability of the station. Particular emphasis should be placed upon the determination of the most advantageous application of on-board computer systems.

RELIABILITY

The space station communication system will be far more complex than any previous space-borne system, and will employ replacement and maintenance techniques to enhance system reliability during the one-year mission. Studies should be planned to develop reliability prediction techniques and verification test programs designed specifically for a system of this type.

WIDE-BAND RECORDING TECHNIQUES

The space station is expected to require recording of data having information bandwidths of 1 to 5 mc. To provide time compression it would be desirable to have read-out rates in excess of these rates. Present wide-band recorders are capable of the recording rate but no time compression is available. In addition, these units are complicated and possess limited recording flexibility. Investigation of the possibility of extending the capabilities of magnetic tape recorders or of employing one of the newer techniques should be made. (Thermoplastic recording is considered the most promising).

POWER SYSTEM

SOLAR CELL MATERIALS AND MANUFACTURING TECHNIQUES

A comparison of silicon, gallium arsenide, cadmium telluride, and thin film cell manufacturing techniques should be made. This effort is required to reduce the cost of the solar cells and ensure the availability of sufficient quantity and quality in the required time period.

SOLAR CELL PANEL DESIGN

To get the maximum power from the solar cell area, concentrator techniques, spectrically reflective filters, and thermal control techniques should be studied, and an optimum design selected.

ENERGY STORAGE

The life of the energy storage subsystem will be one of the factors which determine the active life of the space station. A charge-discharge cycle equivalent to one year of orbital life is within present possibilities, but a three-year cycle is quite difficult to maintain. Regenerative fuel cells and batteries (such as nickel-cadmium) should be thoroughly investigated to determine their cycling capabilities.

POWER GROWTH CAPABILITY

Almost every aircraft developed has had the characteristic of a large increase in power demand late in the development program, and it is possible the power demands of the space station will grow beyond economical utilization of solar cells. A study of the space station to power such things as an oxygen regeneration system, increased power for laboratory experiments, etc., should be made. This could possibly be a solar dynamic system attached to the center hub of the space station.

ENVIRONMENT CONTROL AND LIFE SUPPORT

Integration of the various subsystems into a workable system suitable for the vehicle is always a prime consideration. It will require close coordination with the subsystem development contractor by various groups within NASA and other agencies. The specific problem areas for various aspects of the Life Support Systems are listed on the following pages.

ENVIRONMENTAL CONTROL

Establishment of air conditioning comfort zone parameter values for extended occupancy at reduced pressure atmospheres, and in gas mixtures having a high concentration of oxygen

Establishment of the duty schedules, work activity levels, and metabolic rates for the crew under low gravity conditions

To develop sealing methods to minimize air leakage from the vehicle through permanent joints (mobile junctures), and through reusable joints, such as air locks and docking facilities

Evaluation of air leakage due to meteoroid puncturing and methods of patching or repair and to determine other hazards of meteoroid penetration

To determine the effects of erosion due to micrometeoroid encounters on the vehicle surface and the space radiator surface and to evaluate the erosion resistance of temperature controlling coatings or surface preparations

To evaluate explosion or burning hazard due to meteoroid penetration into chambers as a function of particle size, chamber size, oxygen concentration, and total pressure, and relate to probability of encounter for average and meteor shower conditions. To determine hazards as a function of proximity to flammable materials and flash burn effects on eyes

To study the effects of structure insulation to control heat losses, eliminate condensation on walls, provide sound abatement, and reduce nuclear radiation

To study the methods of storage, resupply, distribution, and handling of pressurizing gasses, whether liquid, supercritical gas, or high-pressure gas

Evaluation of atmospheric contamination and requirements for minimizing the sources

To develop a system and analysis procedure for a flyable trace contamination removal system. To determine compounds not eliminated from the space station atmosphere and the rate of build-up to the maximum allowable concentration

To establish a space radiator design for a high reliability, lightweight, multi-sectionalized system with coolant flow diversion

To establish a system control to prevent coolant freezing in a space radiator's unused section

Development of a regenerable CO_2 absorber system including valves, vacuum vents, etc., to provide reliable operation for long life, with a study which should include comparison between systems using and those not using air dryers such as silica gel

To investigate CO_2 reaction methods for recovering oxygen and providing a minimum of unusable waste products, while requiring low power consumption to be used for long duration space missions. To include in this study the membrane electrodialysis process

To evaluate oxygen recovery methods such as, electrolysis of excess metabolic water or surplus water supply, to produce some of the needed oxygen for long duration missions. To establish a practical, high-reliability system suitable for zero and low g operations

To evaluate requirements or alternative means for long-term storage of low-temperature liquids and gasses. To determine insulation and thermal control methods

To develop valves for venting to vacuum and resealing to provide a leak-proof closure. Applications to include uses having low-to-high usage rates

Development of electronic equipment cooling installation adaptable to direct connection to the coolant circuit and the space radiator. To evaluate a comparison between liquid and gas system

To develop or apply water-recovery processes to water usage requirements for laboratory or other processing to be used aboard the vehicle, other than Life Support Systems. To compare the recovery requirements and system costs with the washing and potable requirements for LSS

Stowage, discharge, or other handling of process wastes from laboratory operations

To establish instrumentation requirements and develop suitable detection and control equipment to maintain the operation of the

Environment Control System and Life Support Systems. Measuring instruments for partial pressure of oxygen, carbon dioxide, and trace gasses (including unexpected types) should be considered

Development of testing procedures and equipment to establish quality control for the space borne components and subsystems

Long term sterilization of potable water

To study the use of 80 percent, or higher, purity-hydrogen peroxide as a source of oxygen, power, and subsequently, water for further electrolysis to oxygen

To investigate the use of glycol coolant (and other equivalent fluids) to evaluate the composition, and corrosion and phase characteristics as functions of temperature and pumping characteristics

WATER MANAGEMENT

In the general area of water reclamation, studies are required for development of continuous recovery systems with low power drain. Trade-offs on utilizing individual subsystems for potable water from dehumidification system water, wash water – or better, from urine and wash water (singly or combined) – fecal water, and food preparation water waste have to be reviewed. Systems should be designed and rigorously tested for the mechanical, chemical and, especially, for the bacteriological aspects of long term operation.

Presently available vapor compression systems need evaluation for long-term service and maintenance requirements, odor and contaminant build up, and space contamination, if space vacuum is to be utilized in any part of the process. Furthermore, the suitability of present systems, with respect to the acceleration and vibration forces, remains to be proven. A further development points to continuous system, smaller weight, and small power drain. This may come about with improvements in the compressor. Other studies are needed to:

1. Determine the procedures and treatment necessary for water wastes, storage, and collection for a zero or low G application to prevent clogging of lines and harmful bacteria growth

2. Develop methods for long term sterilization of potable and human cleansing water and storage containers

3. Develop methods for recovery of usable water from the waste liquids, and separation of the unusable wastes. Provide treatment and storage for the system's products

4. Devise precautionary measures to prevent contamination of the purified water from any of the normal inputs of impure water during normal system operation, and in event of a malfunction in the system

5. Develop instrumentation for presentation of system monitoring information and for determining the purity of the water supply

6. Development of a suitable water separator to remove and coalesce entrained water

7. Investigate effects of materials and fabrication methods relative to providing and maintaining the purity requirements for the water in the Life Support Systems

8. Investigate the electrolysis of water methodology to further development of a continuous generation of oxygen and hydrogen at low gravity (1/4 to 1/3 g) conditions. It may not be necessary to operate at zero g condition; nevertheless, the gas separation will need investigation along with need for additional circulation of the electrolyte.

WASTE MANAGEMENT

Areas requiring further study within this subsystem are the collection devices, pretreatment and storage for urine, for feces (temporary or long term), for wash water and for food and other miscellaneous wastes.

Critical areas would include overall contamination and odor control, sterilization of waste fluid systems, and sanitary disposal (cold storage, incineration, sterilized overboard discharge) of any and all wastes, with minimum power consumption.

PERSONAL HYGIENE

Problem areas here include the methods for personal cleansing and bathing, availability of hot water, the types of cleansing agents compatible with water reclamation processes, and sterilization and decontamination of personal hygiene equipment. The general problem of suitable clothing (disposable or non-disposable type) and the associated laundering will need further study.

An important adjunct, the dispensary, will need further development as to type of medicinals and first aid items for minor accidents. There should be suitable instructions for handling corpses in case of death.

FOOD MANAGEMENT

The problems in the area of food management, including storage, have been reasonably resolved for orbiting and space vehicles having short durations; however, studies should be conducted for extending coverage to long duration missions and to integrating the system with those of water management, waste management, personal hygiene, and the environment control system. Effects of diet on the psychology, as well as physiology, of the crew should be determined. The use of non-residue foods, as planned for the short term missions, would seem to be illogical for one year missions. The practices of religious, as well as medically prescribed, or natural environment long-term fasting should be reviewed for incorporation with applicable methods for space stations and other long-range duration missions. There are several miscellaneous problems associated with long term storage of foods under space station conditions. The development of multipurpose containers for storage, reconstruction, and subsequent disposal of food waste is desirable.

Methods for detection of microbial agents in food deteriorating in storage may be also necessary. Emergency food supplies and drinking water are currently available, and should not pose difficulties.

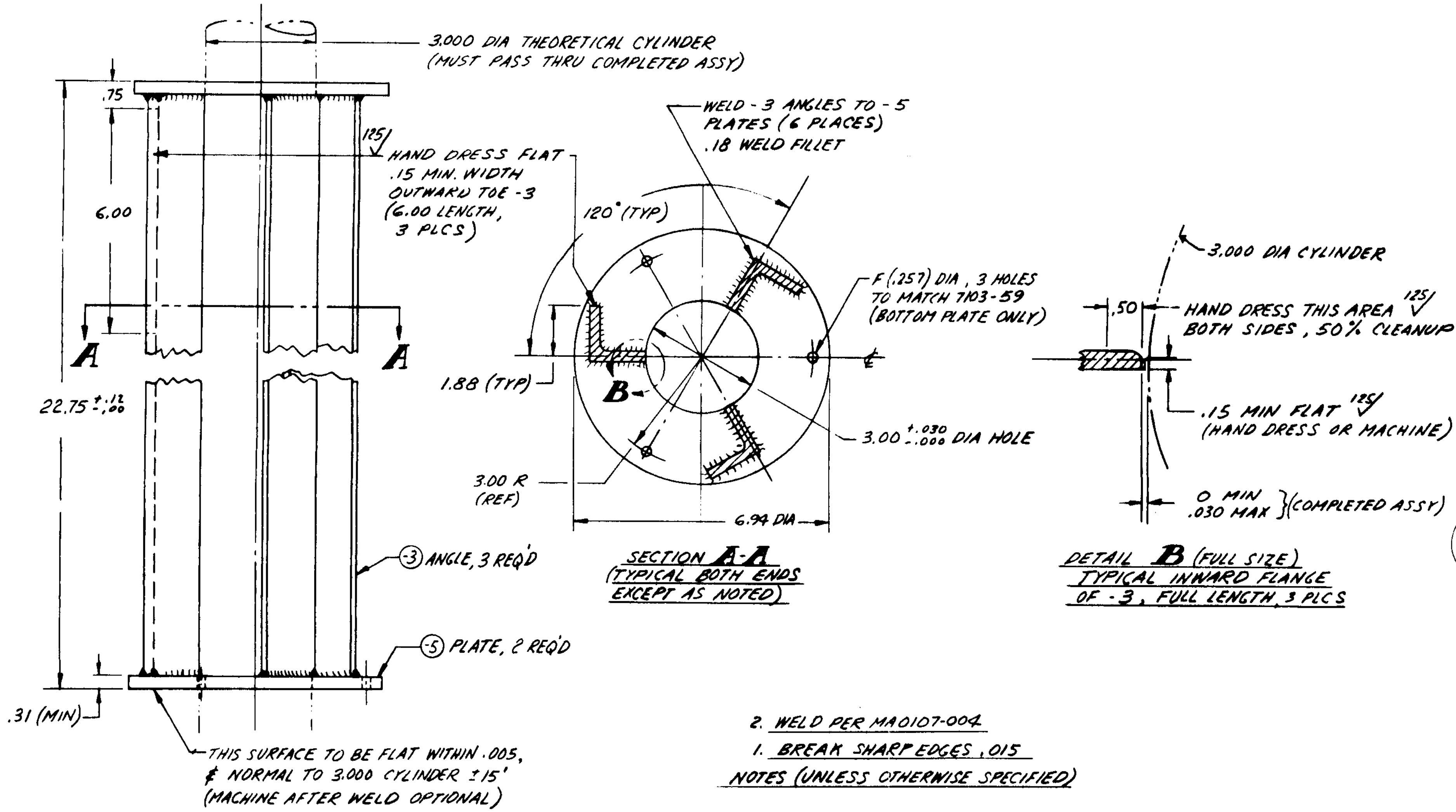
APPENDIX

DESIGN DRAWINGS

A complete set of the detail design drawings on the 1/10-scale model of the SDSS is included in this section. The numbering sequence appears to indicate that certain drawings are missing; however, this discrepancy is due to the method used in assigning drawing numbers. The following drawings are included:

Drawing No.	Title
7103-50	Complete Assembly
7103-51A	Rim Module Assembly
7103-52A	Assembly - Spoke
7103-54	Stand Assembly - Support
7103-56	Mechanism Installation - Hub
7103-58	Link Installation - Module Hinge
7103-59B	Base Assembly - Hub
7103-60	External Fairing - Hub
7103-61	Cage Assembly - Hub Mechanism
7103-62	Sling Assembly - Support
7103-66	Hanger Assembly - Hub Suspension
7103-67	Bracket - Spoke Extension Spring
7103-68	Spring - Spoke Extension
7103-69	Hanger - Spoke Extension Cables
7103-70	Keeper - Spoke Extension Cables
7103-71	Bracket Installation Spoke Extension Cable
7103-72	Bracket - Spoke Extension Cable
7103-73	Cable Assembly - Hub Suspension
7103-74	Cable Assembly - Spoke Extension
7103-75	Stud - Hub Suspension Cable Attach

Drawing No.	Title
7103-76	Bolt - Spoke Extension Adjusting
7103-77	Switch Installation - Module Actuator
7103-78A	Rework Drawing - Module Actuator Fitting
7103-80	Switch Installation - Spoke Actuator
7103-86	Rework Drawing - Rim Module Spoke Swivel
7103-88	Sketch - Model Payload Adapter Fairing
7103-90	Specification Drawing - Base Mounted Hoist
7103-100	Control Console - Schematic Wiring Design
7103-101	Logic Diagram - Control Console
627W52	Actuator - Linear Electrical (Outline)
627W52A	Actuator - Linear Electrical (Detailed)



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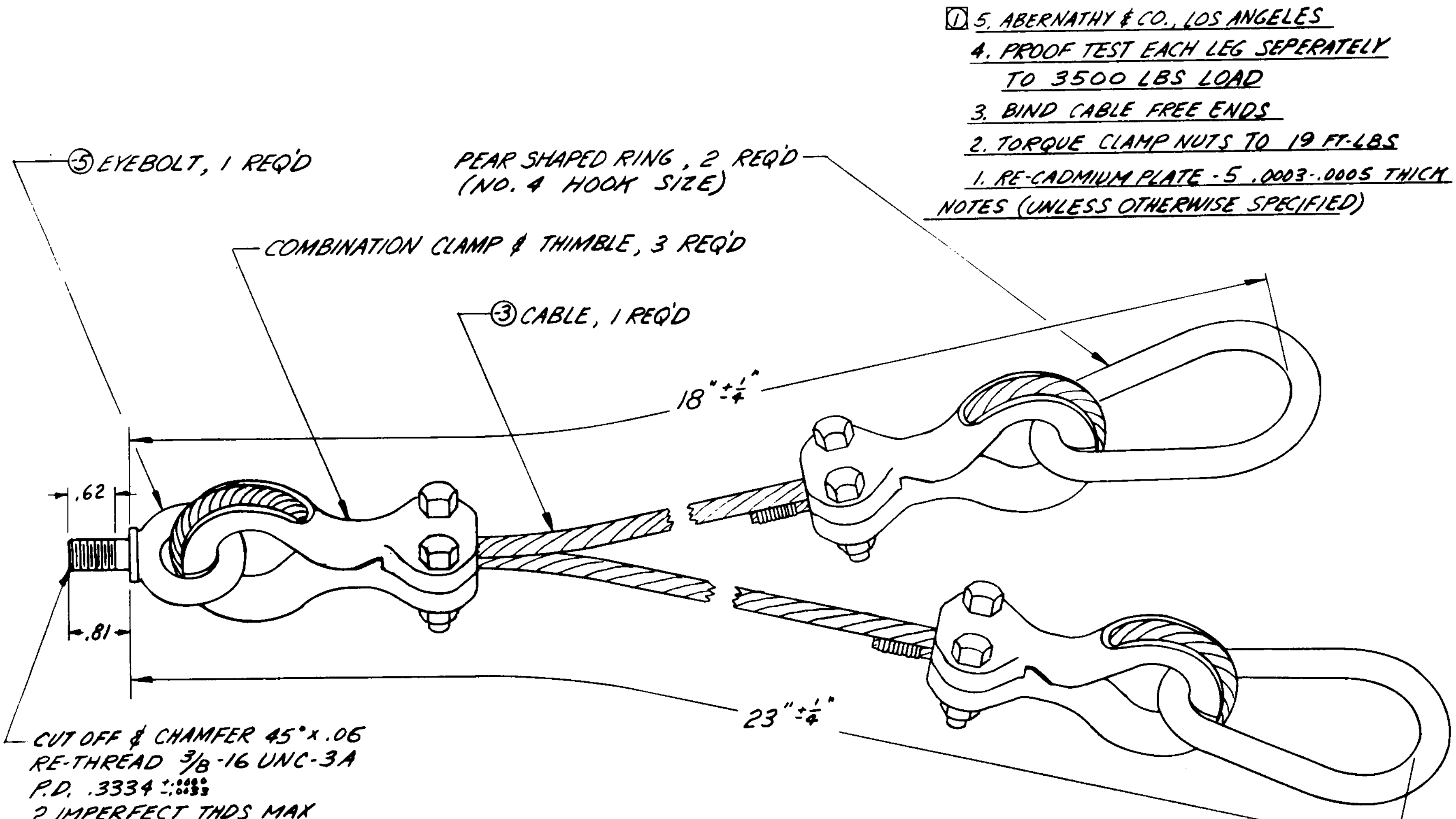
											004
					2	-5	PLATE		LOW CARBON STEEL PLATE	3/8 × 7.00 × 7.00 COMMERCIAL	003
					3	-3	ANGLE		LOW CARBON STEEL ANGLE	2 × 2 × 1/4 THICK × 22.5 COMMERCIAL	002
						7103-61	ASSEMBLY				001

LIST OF MATERIAL OR PARTS LIST

Drawing 7103-61 Cage Assembly - Hub Mechanism



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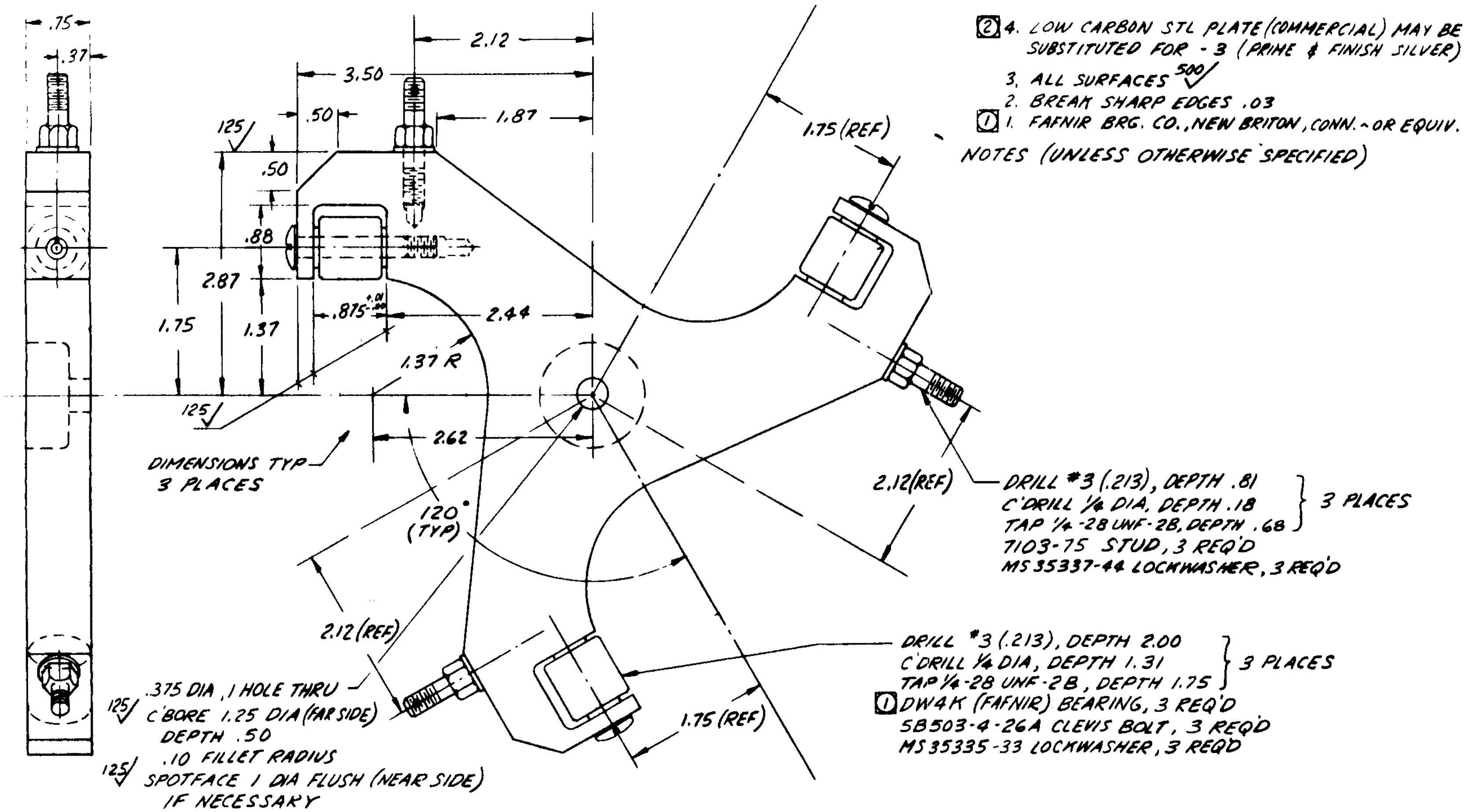
					2	PEAR SHAPED	RING		NO. 4 HOOK SIZE (COMMERCIAL)		005
					3	COMBINATION CLAMP & THIMBLE			1/4 CABLE SIZE	NEWCO OR EQUIV.	004
					1	-5	EYEBOLT		MAKE FROM	NAS1053-06-10	003
					1	-3	CABLE		CARBON STL WIRE ROPE	1/4 DIA x 50 MIL-W-1511	002
						7103-62	ASSEMBLY				001

LIST OF MATERIAL OR PARTS LIST

Drawing 7103-62 Sling Assembly - Support



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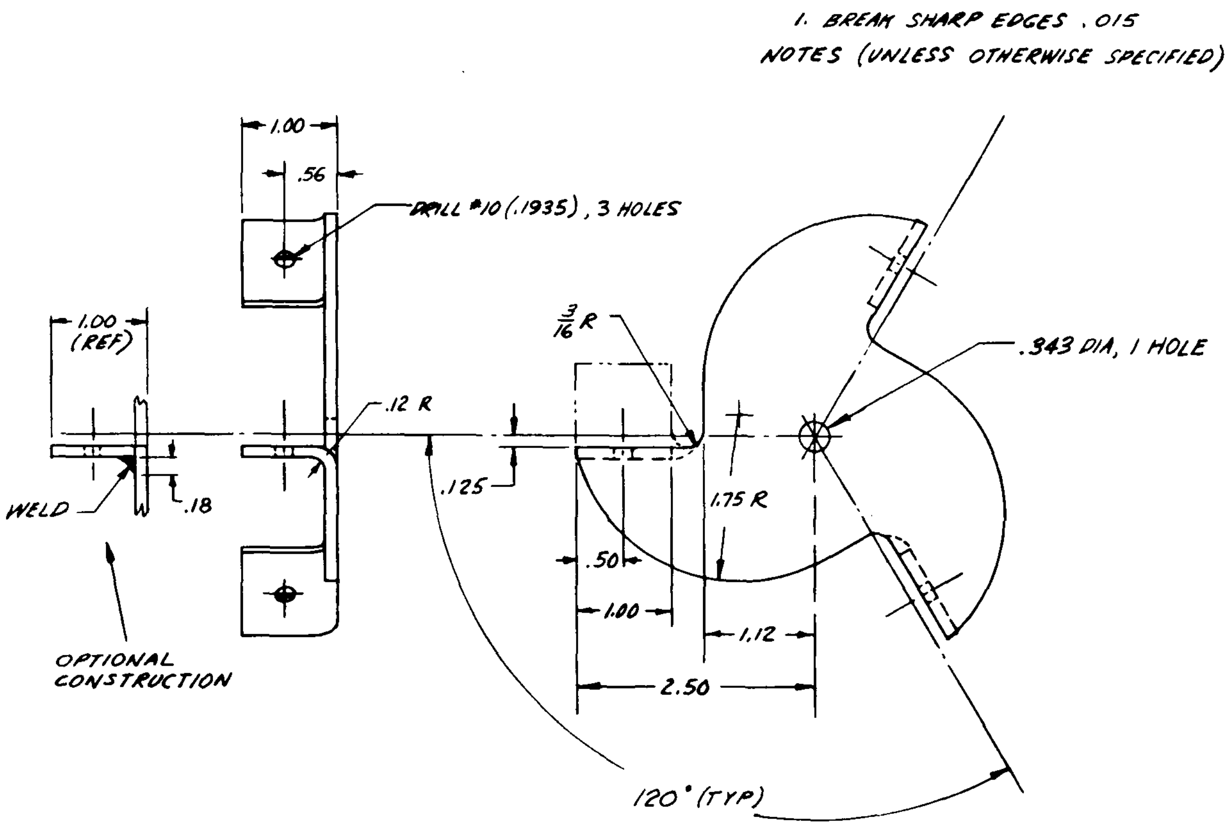
						3	7103-75	STUD				
1						3	DW4K	BEARING			FAFNIR OR EQUIV.	
						3	5B503-4-26A	BOLT				005
						3	MS 35337-44	WASHER				004
						3	MS 35335-33	WASHER				003
2						1	-3	BRACKET		2024-T42 AL PLATE	1/4 x 8 x 8 QQ-A-355	002
							7103-66	ASSY				001

LIST OF MATERIAL OR PARTS LIST

Drawing 7103-66 Hanger Assembly - Hub Suspension



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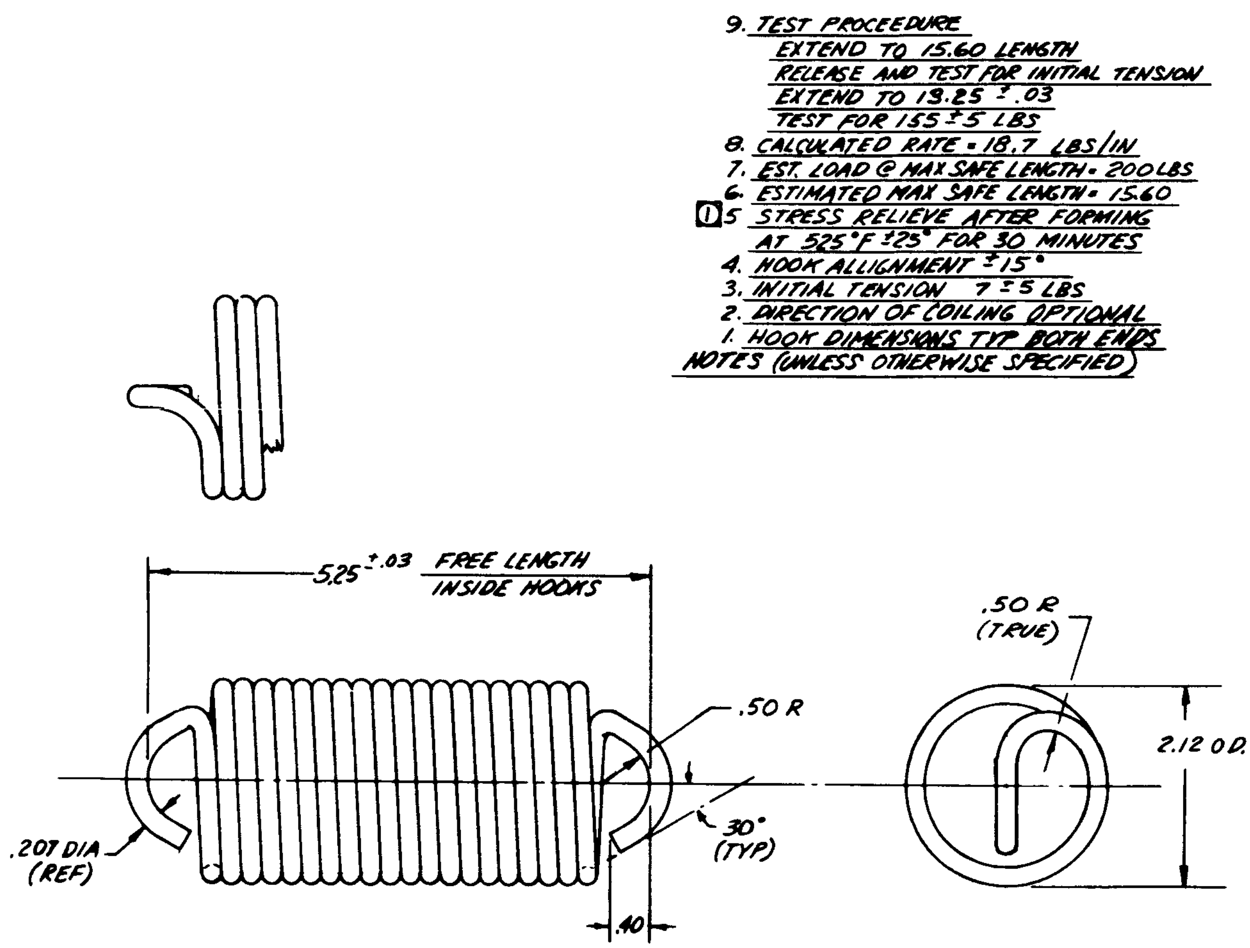
											005
											004
											003
											002
						7103-67	BRACKET		LOW CARBON STL SHT	.120 x 5 x 5 COMMERCIAL	001

LIST OF MATERIAL OR PARTS LIST

Drawing 7103-67 Bracket - Spoke Extension Spring



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											005
											004
											003
											002
						7103-68	SPRING		STEEL MUSIC WIRE	.207 DIA × 150 QQ-W-470	001

LIST OF MATERIAL OR PARTS LIST

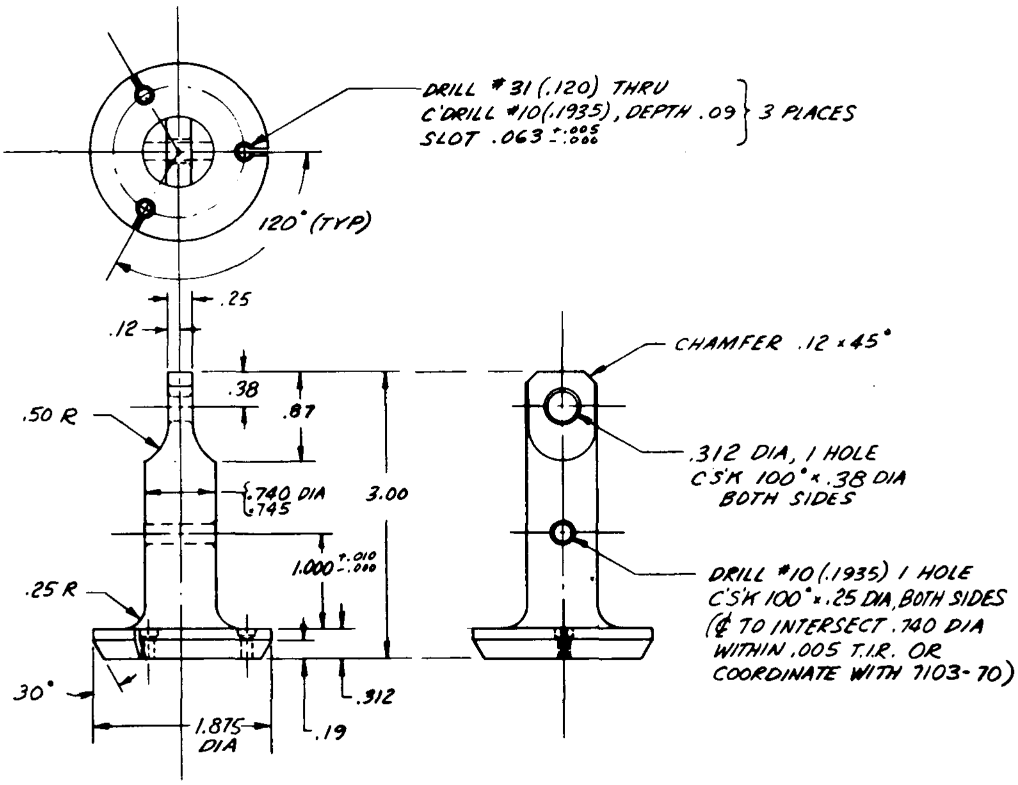
Drawing 7103-68 Spring - Spoke Extension

1 3. LOW CARBON STL BAR (COMMERCIAL) MAY BE SUBSTITUTED ~ CADMIUM PLATE .0003-.0005 THICK

2. ALL MACHINED SURFACES 250/

1. BREAK SHARP EDGES .010

NOTES (UNLESS OTHERWISE SPECIFIED)



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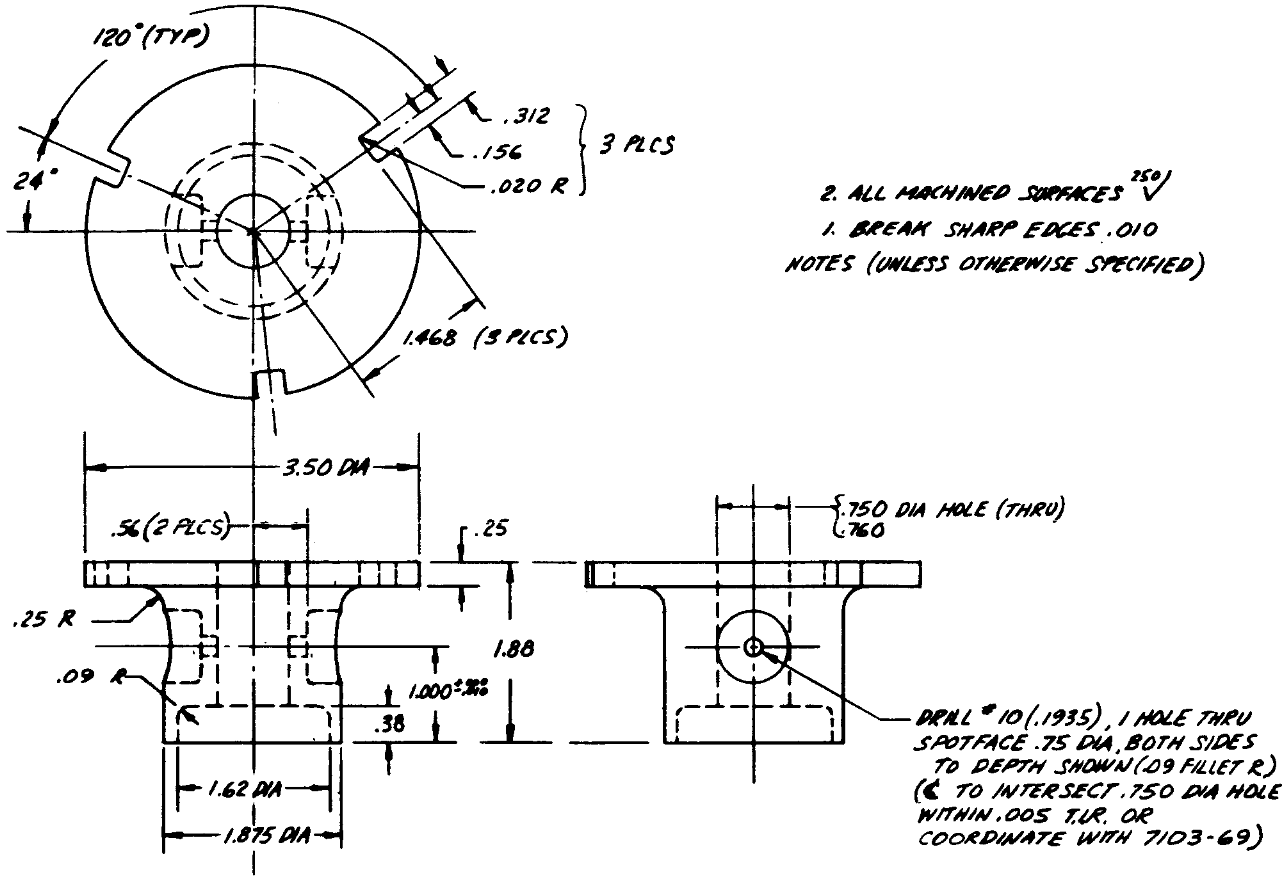
											005
											004
											003
											002
						7103-69	HANGER		2024-T42 AL BAR	1.875 DIA × 3 QQ-A-268 - TEMP T-42	001

LIST OF MATERIAL OR PARTS LIST

Drawing 7103-69 Hanger - Spoke Extension Cables



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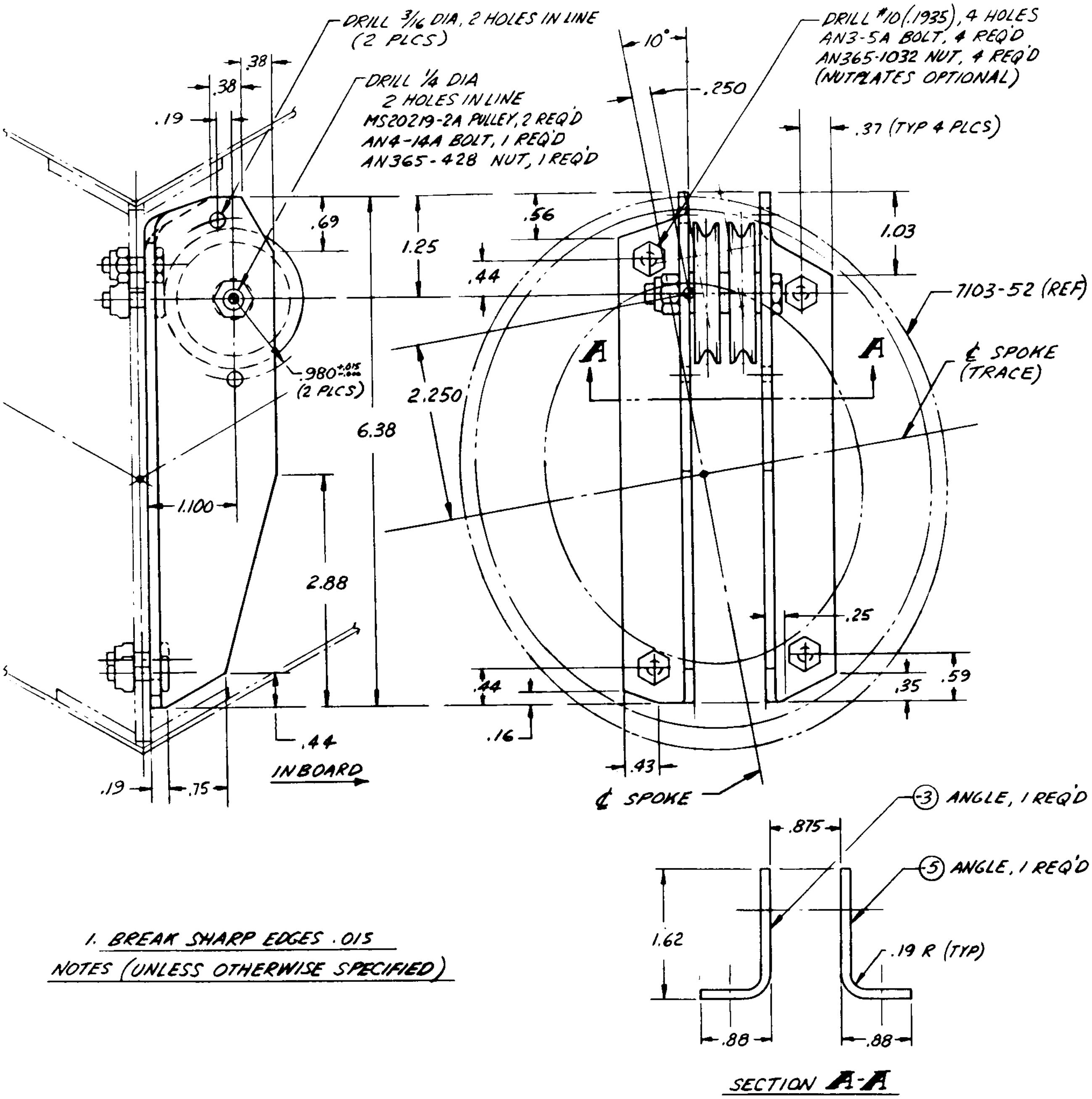
											005
											004
											003
											002
						7103-70	KEEPER		COT. FAB. PHENOLIC RESIN SHEET	2 × 3.5 × 3.5 MIL-P-15035, TYPE FBM	001

LIST OF MATERIAL OR PARTS LIST

Drawing 7103-70 Keeper - Spoke Extension Cables



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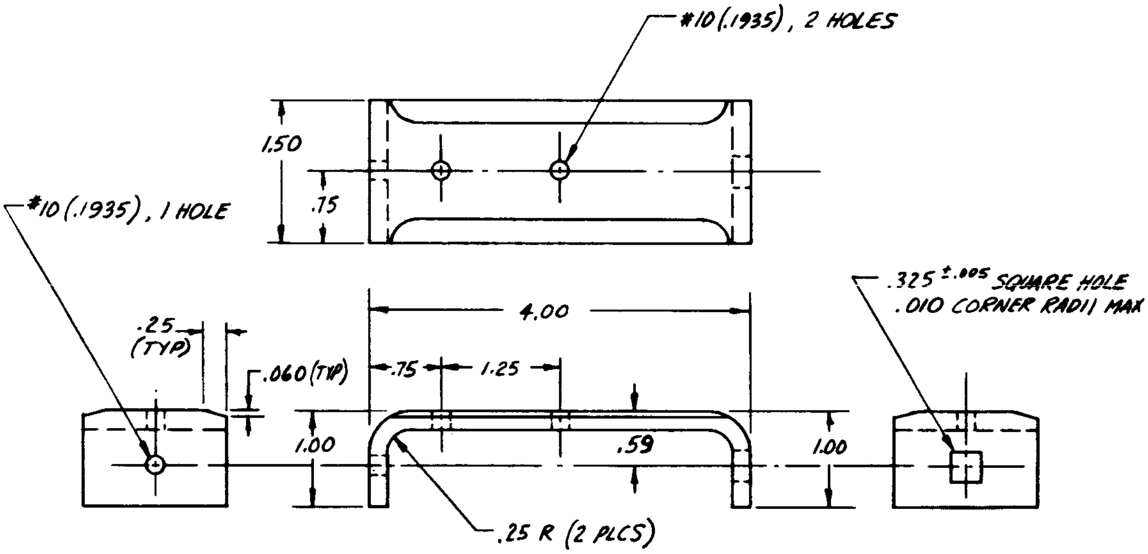
					4	AN365-1032	NUT				
					1	AN4-14A	BOLT				
					4	AN3-5A	BOLT				005
					2	MS20219-2A	PULLEY				004
					1	-5	ANGLE		2024-0 CLAD SHT	.125 × 2.5 × 6.5 QQ-A-362	003
					1	-3	ANGLE		2024-0 CLAD SHT	.125 × 2.5 × 6.5 QQ-A-362	002
						7103-71	INSTALLATION				001

LIST OF MATERIAL OR PARTS LIST

Drawing 7103-71 Bracket Installation Spoke Extension Cable

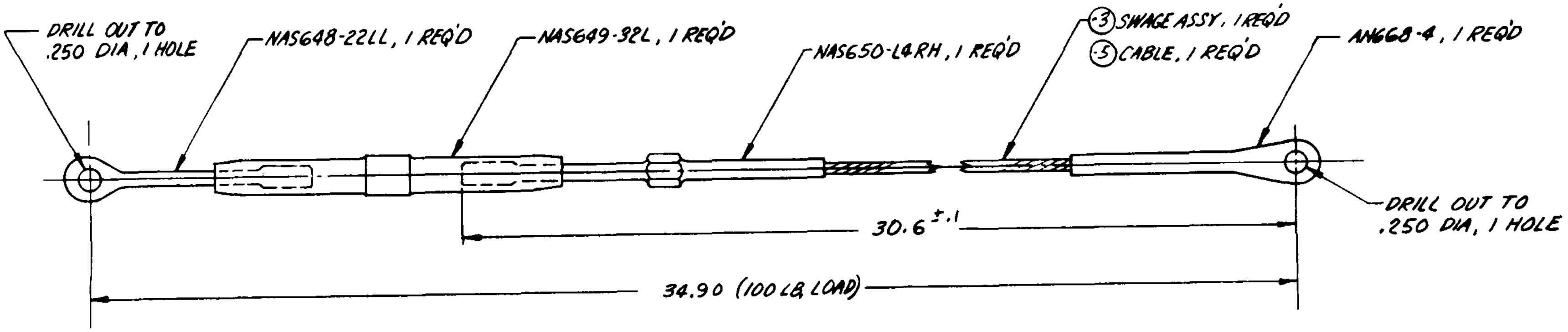
2. BREAK SHARP EDGES .015
1. FABRICATED SURFACES 250 √
NOTES (UNLESS OTHERWISE SPECIFIED)



											005
											004
											003
											002
						7103-72	BRACKET		2024-0 CLAD SHT	.190 × 1.5 × 6 QQ-A-362	001
QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA: SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
LIST OF MATERIAL OR PARTS LIST											

Drawing 7103-72 Bracket - Spoke Extension Cable

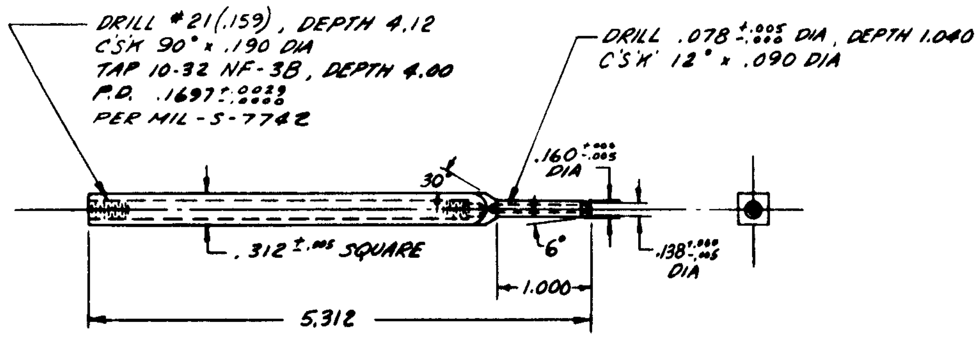
2. TEST ASSEMBLY AT 1200 LBS PER MIL-C-5688 (FA6-1)
1. SWAGE TERMINALS PER MIL-T-6117 (FA6-1)
NOTES (UNLESS OTHERWISE SPECIFIED)



QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA: SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
				1		AN668-4	TERMINAL				
				1		NAS650-L4RH	TERMINAL				
					1	NAS649-32L	BARREL				005
					1	NAS648-22LL	TERMINAL				004
				1		-5	CABLE		CARBON STEEL WIRE ROPE	1/8 DIA × 27 MIL-W-1511	003
					1	-3	SWAGE ASSY				002
				-3		7103-73	CABLE ASSY				001

LIST OF MATERIAL OR PARTS LIST

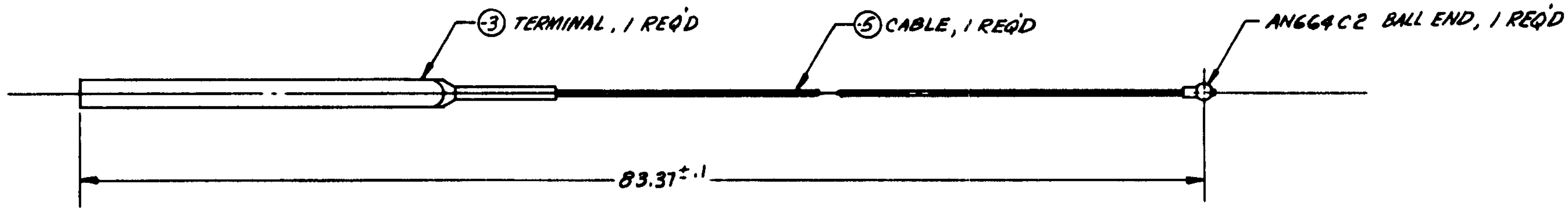
Drawing 7103-73 Cable Assembly - Hub Suspension



DETAIL OF -3

4. ALL MACHINED SURFACES 125√ (-3)
3. BREAK SHARP EDGES .015 (-3)
2. TEST ASSEMBLY AT 290 LBS PER MIL-C-5688(FAG-1)
1. SWAGE TERMINALS PER MIL-T-6117(FAG-1)

NOTES (UNLESS OTHERWISE SPECIFIED)

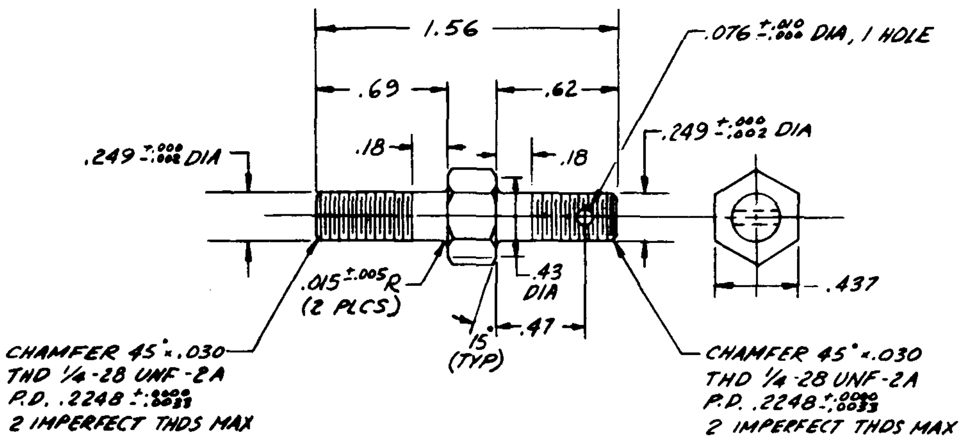


QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA: SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
											005
					1	AN664C2	BALL END				004
					1	-5	CABLE		CARBON STEEL WIRE ROPE	1/16 DIA x 79.2 MIL-W-1511	003
					1	-3	TERMINAL		4130 STL BAR	5/16 SQUARE x 5.312 MIL-S-6758, COND (D)(4)	002
						7103-74	CABLE ASSY				001

LIST OF MATERIAL OR PARTS LIST

Drawing 7103-74 Cable Assembly - Spoke Extension

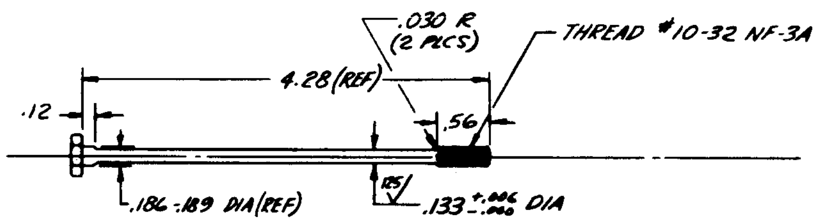
3. REMOVE ALL BURRS
2. ALL DIMENSIONS BEFORE PLATING
1. ALL MACHINED SURFACES 63√
NOTES (UNLESS OTHERWISE SPECIFIED)



QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA: SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
											005
											004
											003
											002
						7103-75	STUD		4130 STL BAR	7/16 HEX × 1.56 MIL-S-6758, COND (F)(4)	001

LIST OF MATERIAL OR PARTS LIST

Drawing 7103-75 Stud - Hub Suspension Cable Attach

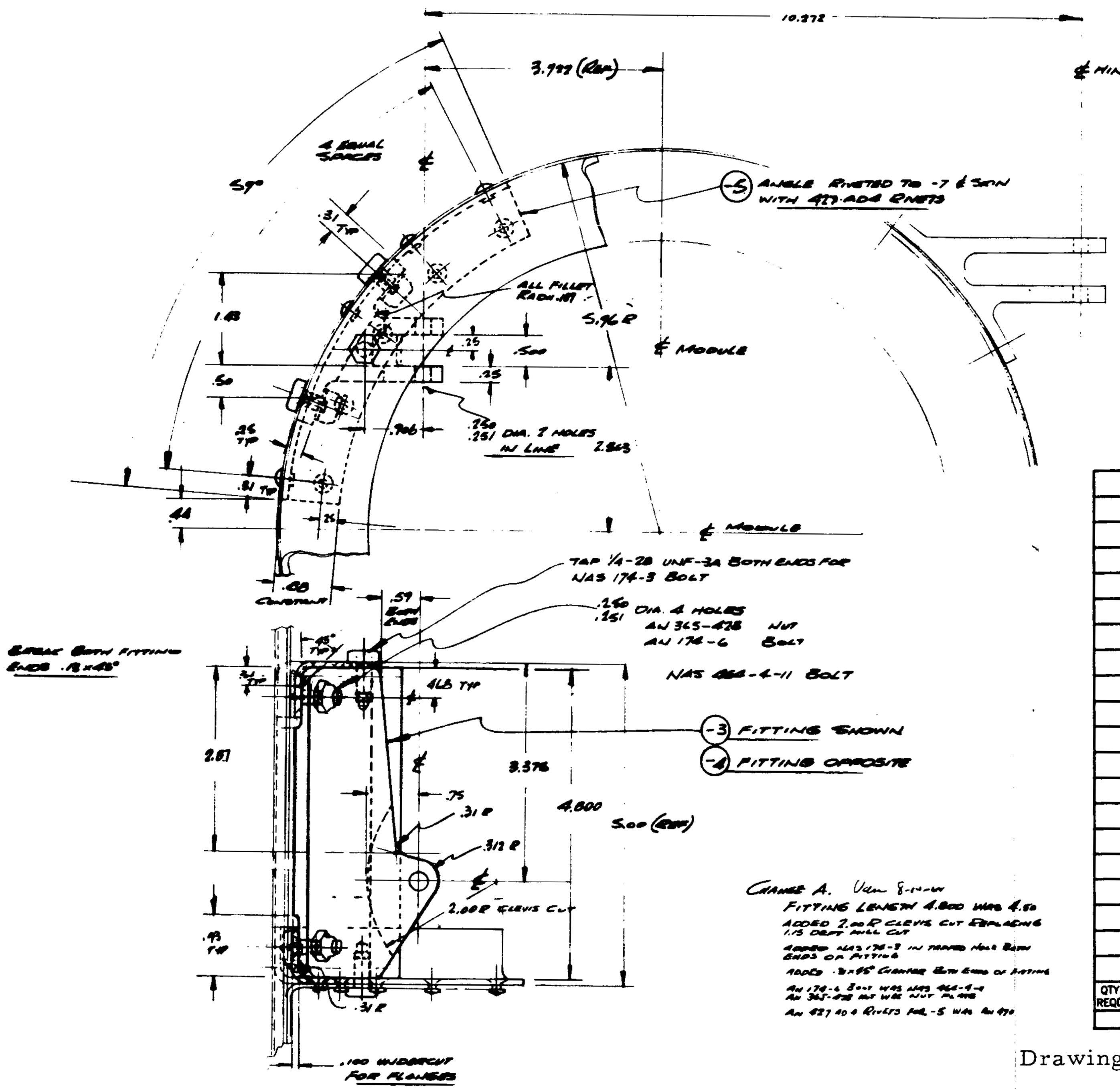


QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA: SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
											005
											004
											003
											002
						7103-76	BOLT		MAKE FROM	AN3-42A	001

LIST OF MATERIAL OR PARTS LIST

Drawing 7103-76 Bolt - Spoke Extension Adjusting

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVED
	1. MAY BE REWORKED 3. RECORD CHANGE 2. CANNOT BE REWORKED 4. NOW SHOP PRACTICE 5. PARTS MADE OK		



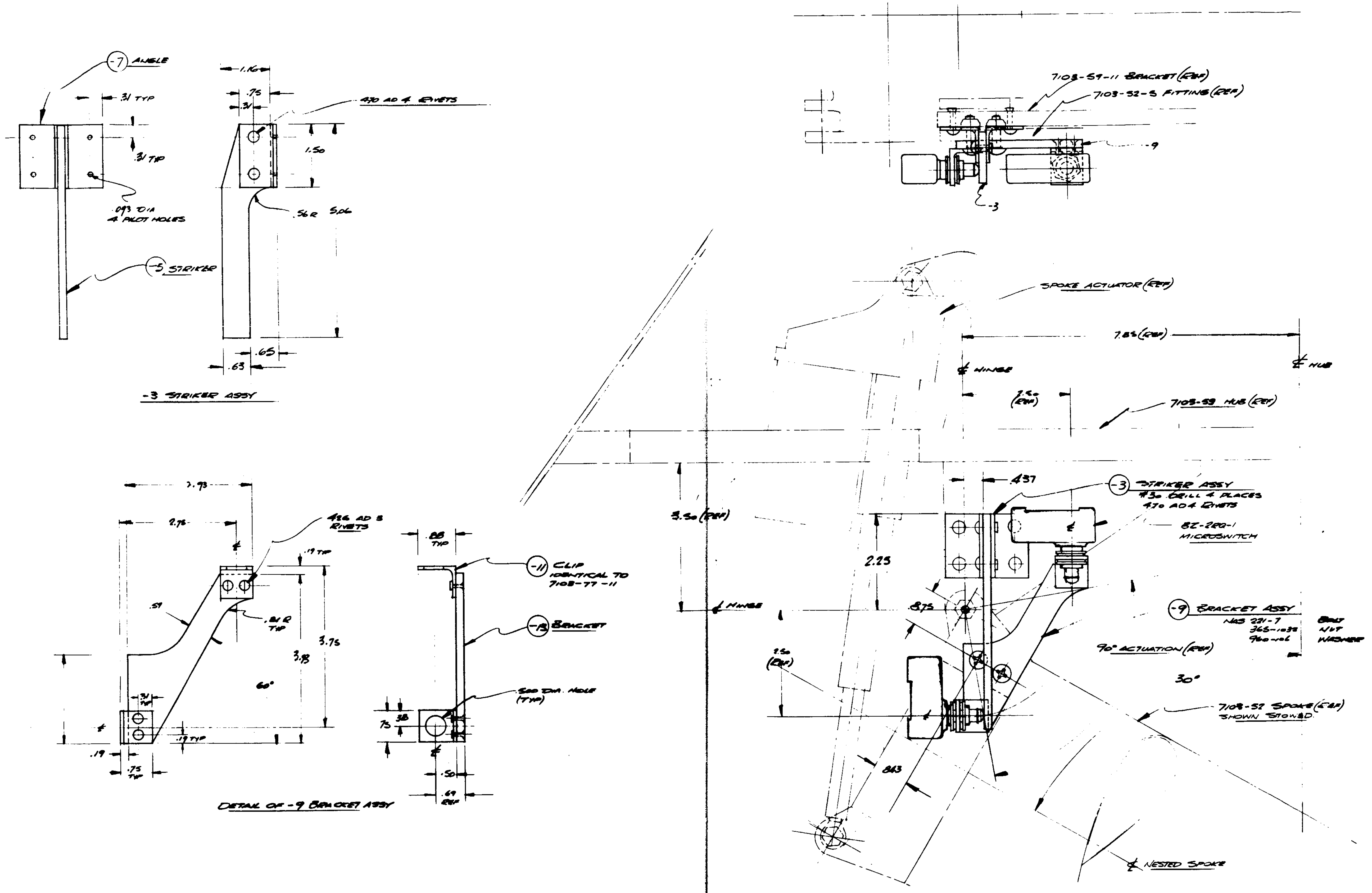
NOTE

THIS DWG REPLACES 7103-81-17 FITTING AND ITS METHOD OF ATTACHMENT.

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA: SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
											020
											019
											018
											017
											016
											015
											014
											013
											012
						24	NAS 174-3	BOLT			011
						48	NAS 174-6	BOLT			010
						48	AN 365-428	NUT			009
											008
											007
											006
											005
											004
					12	-5	ANGLE		6061-T6 ALUM ALLOY SHEET	.100 x 5 x 7 WW-T-700	003
					6	-4	FITTING OPPOSITE		2024-T4 ALUM ALLOY BAR	2 x 3 x 6.0 QQ-A-267 TEMP T4	002
					6	-3	FITTING SHOWN		2024-T4 ALUM ALLOY BAR	2 x 3 x 6.0 QQ-A-267 TEMP T4	001

LIST OF MATERIAL OR PARTS LIST

Drawing 7103-78A Rework Drawing - Module Actuator Fitting

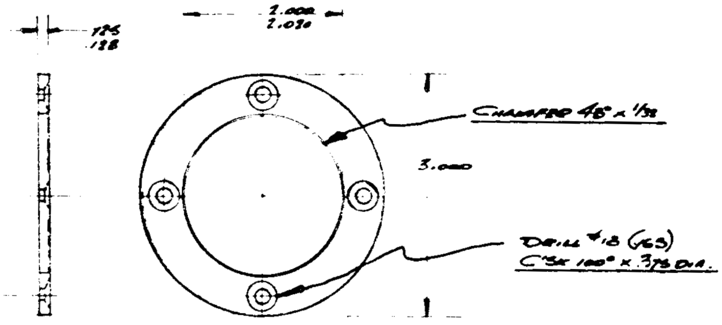


QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA: SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
					6	960-10L	WASHER				
					6	365-1032	NUT				
					6	NAS 221-7	BOLT				
					3	-13	BRACKET		2024-T4 AL ALLOY PLATE (COMM'L)	.187 × 3 × 4	
					6	-11	CLIP		2024-T4 AL ALLOY EXTRUSION (COMM'L)	3/4 × 3/4 × 7/8 ANGLE .062 THICK	005
					3	-9	BRACKET ASSY		CONSISTS OF	-11, & -13	004
					6	-7	ANGLE		2024-T4 AL ALLOY EXTRUSION (COMM'L)	7/8 × 7/8 × 1 1/2 .062 THICK	003
					3	-5	STRIKER		2024-T4 AL ALLOY PLATE (COMM'L)	.187 × 1 1/16 × 5 1/16	002
					3	-3	STRIKER ASSY		CONSISTS OF	-5 & -7	001

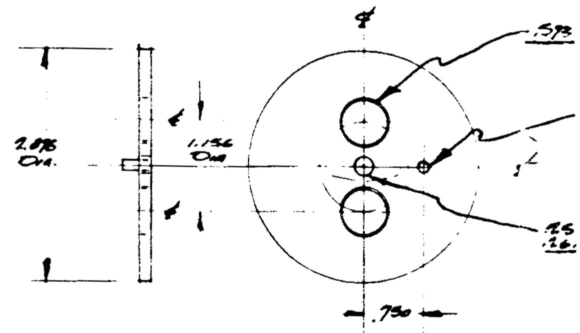
LIST OF MATERIAL OR PARTS LIST

Drawing 7103-80 Switch Installation - Spoke Actuator

NORTH

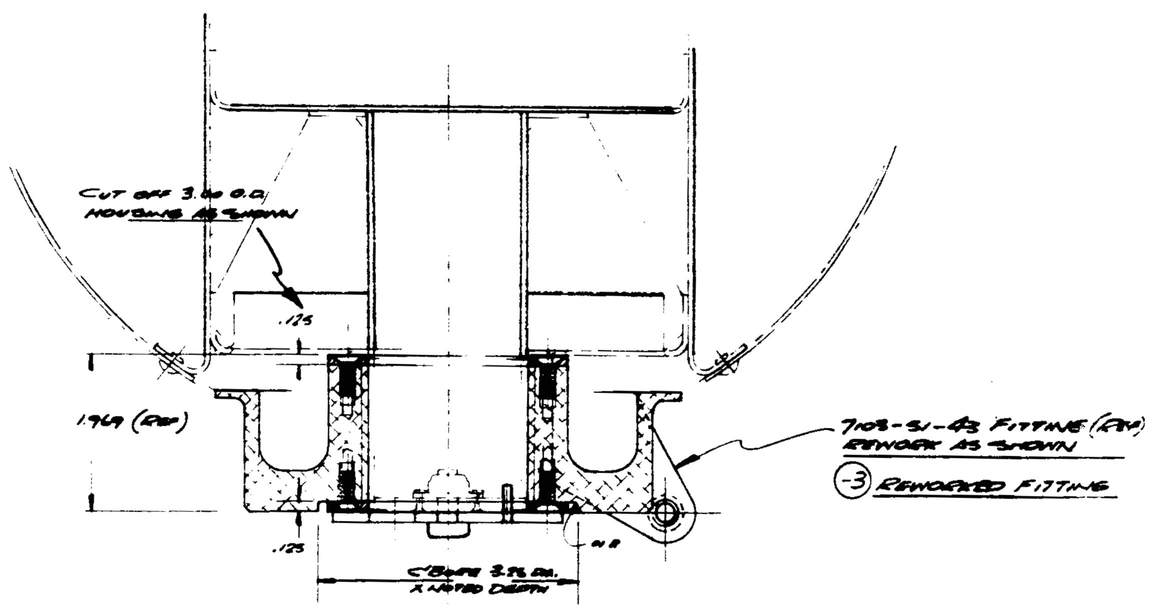


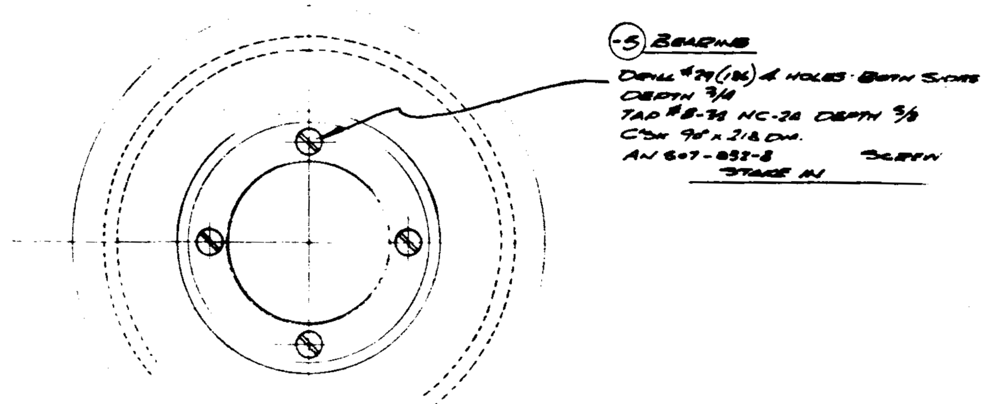
DETAIL OF -5 BEARING



DETAIL OF -9 PLATE

NOTE
THIS PART REPLACE.





DIA. 2 HOLES CSK BOTH SIDES 90° x .625 DIA.
(DUPLICATE IN 7103-51-47)

(-7) DOWEL

— DRILL & PRESS IN .125 DIA. DOWEL
MATCH .130/.131 DIA. HOLE IN 7103-51-47 PLUG (REF)

DIA. HOLE (REF)

TO PLATE

7103-51-41 (SCRAP)

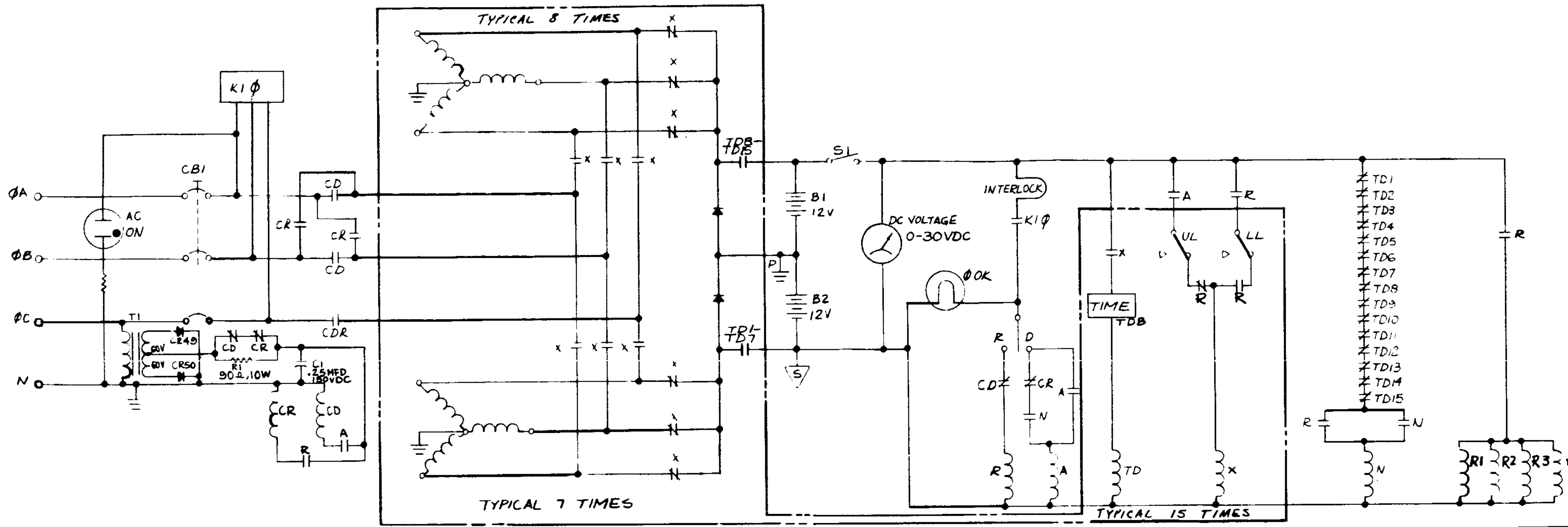
REVISIONS				
SYM	DESCRIPTION		DATE	APPROVED
	1. MAY BE REWORKED 3. RECORD CHANGE 2. CANNOT BE REWORKED 4. NOW SHOP PRACTICE 5. PARTS MADE OK	DISPOS		

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA: SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
											020
											019
											018
											017
											016
											015
											014
											013
											012
											011
											010
											009
											008
											007
											006
											005
					3	-9	PLATE		1095 STL	.1[illegible] x 2.[illegible] x 2.[illegible] COMM'L PLATE	004
					3	-7	DOWEL		1095 STL	.125 DIA. x 1/8 COMM'L ROD	003
					6	-5	BEARING		HARD BRASS	.156 x 1.0 x 1.0 COMM'L PLATE	002
					3	-3	FITTING		REWORK 7103-51-48		001
					(TOTAL)	LIST OF MATERIAL OR PARTS LIST					

Drawing 7103-86 Rework Drawing - Rim Module Spoke Swivel

Drawing 7103-88 Sketch - Model Payload Adapter Fairing

Drawing 7103-100 Control Console - Schematic Wiring Design



QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
											020
											019
											018
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											016
											015
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											013
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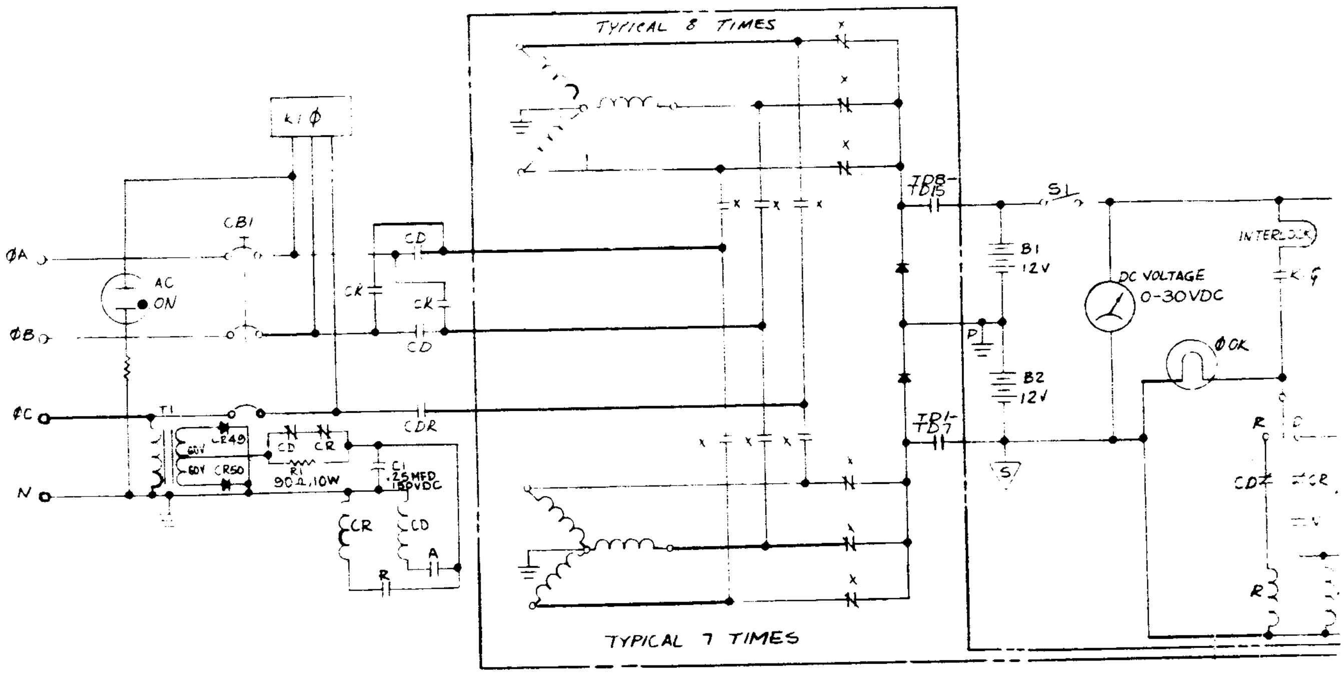
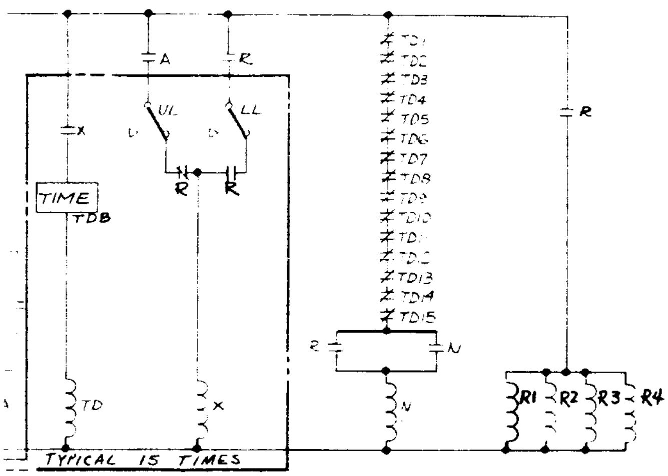
											011
											010
											009
											008
											007
											006
											005
											004
											003
											002
											001

LIST OF MATERIAL OR PARTS LIST

Drawing 7103-101 Logic Diagram - Control Console



TYPICAL 8 TIMES
K1 Φ
CB1
ΦA
AC
ON
ΦB
ΦC
N
T1
CR49
CR50
60V
CD
CR
R1
90Ω,10W
C1
.25MFD
150VDC
CK
CDR
A
R
TD8-TD15
TD1-TD7
S1
B1
12V
B2
12V
P
S
INTERLOCK
K
DC VOLTAGE
0-30VDC
ΦOK
CD7
TYPICAL 7 TIMES



											020
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QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	CODE IDENT	MATERIAL	DATA SPECIFICATION SIZES, NOTES, SUPPLIERS	LINE NO.
						LIST OF MATERIAL OR PARTS LIST					

Drawing 7103-101 Logic Diagram - Control Console